Jackson River Benthic TMDL Meeting

Covington, Virginia

June 8, 2007

THE Louis Berger Group, INC.

Agenda

- Describe Model Implementation for 2000 and 2001 (Segmentation Boundaries, Calibration/Validation Results)
- Describe Model Implementation for 2006 (Current Conditions)
- Describe Allocation Strategy
- Present and Illustrate the Flow Pulse Scenario
- Describe Next Steps

Description of the Models

- **Instream Model**
  - Water Analysis Simulation Program Version 7.2 (WASP7.2, July 2006):

    Windows based, U.S. EPA generalized modeling framework

    WASP (version 7.2) can be applied for unsteady flow, one-dimensional in rivers and three-dimensional in lakes and estuaries

    WASP7.2 includes periphyton kinetic in the eutrophication module However, periphyton is not linked to advective and dispersive transport

- **Watershed Model**
  - Hydrologic Simulation FORTRAN (HSPF)

    State of the art modeling system and EPA approved approach (Being implemented by the EPA Chesapeake Bay Program HSPF)

    Hydrologic, watershed-based water quality model (rainfall variations and activities/uses related to nutrients loading)

    Predicts runoff quantity and quality then routing it through the reaches

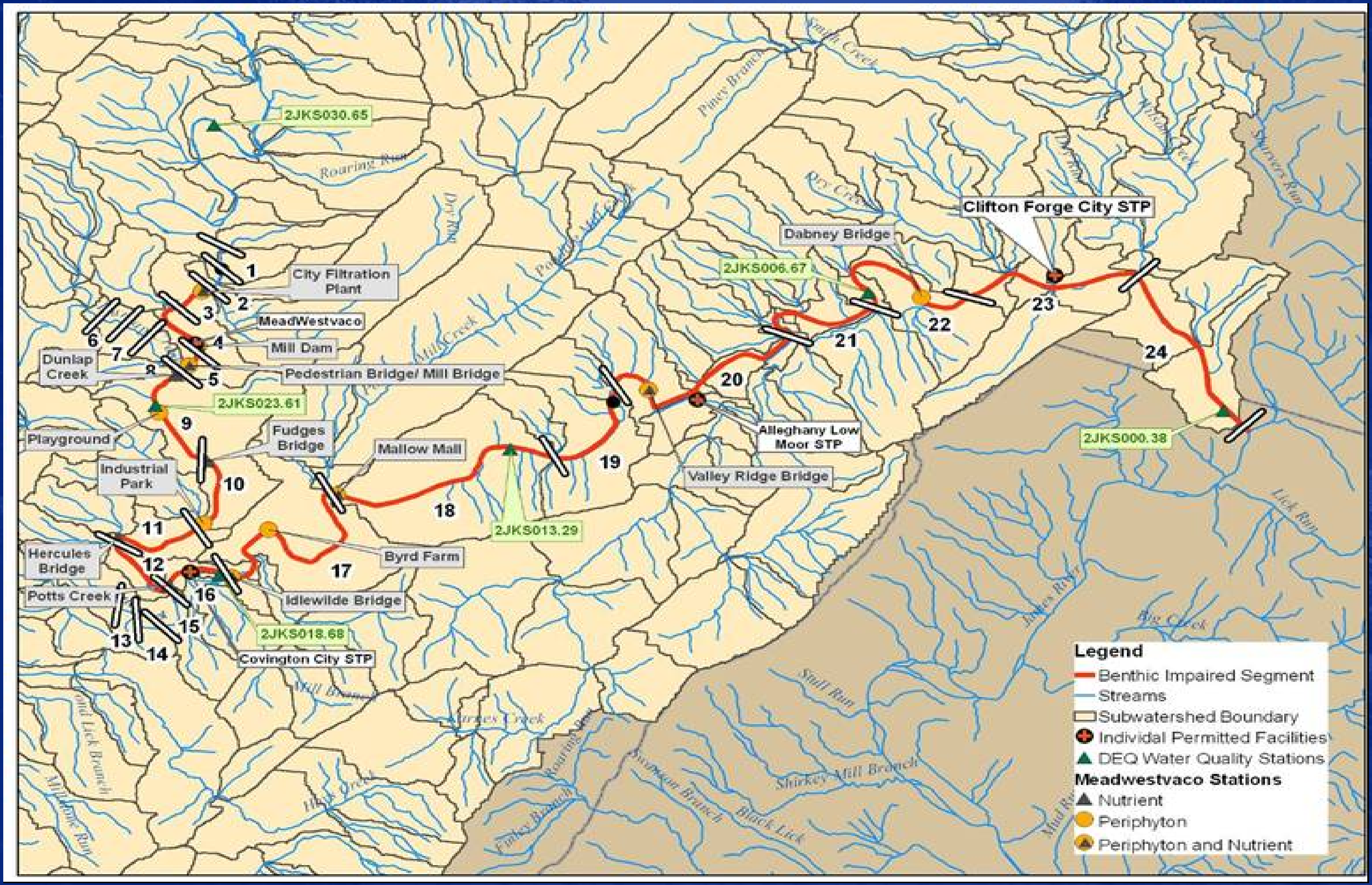
Modeling Strategy

- Use the WASP7 model to simulate nutrient fate and periphyton growth
- Estimate NPS contributions using the HSPF model (time series)
- Link NPS file to the WASP Water Quality Model
- Calibrate and validate the model for June through October of 2000 and 2001
- Apply the calibrated/validated model for existing conditions (2006)

Jackson River Model Segmentation

- Based on location of catchments, major point sources, water quality monitoring stations, and major tributaries (Dunlap and Potts Creek)
- Consists of 24 segments (18 mainstem-segments and 6 tributary- segments)

Jackson River Model Segmentation

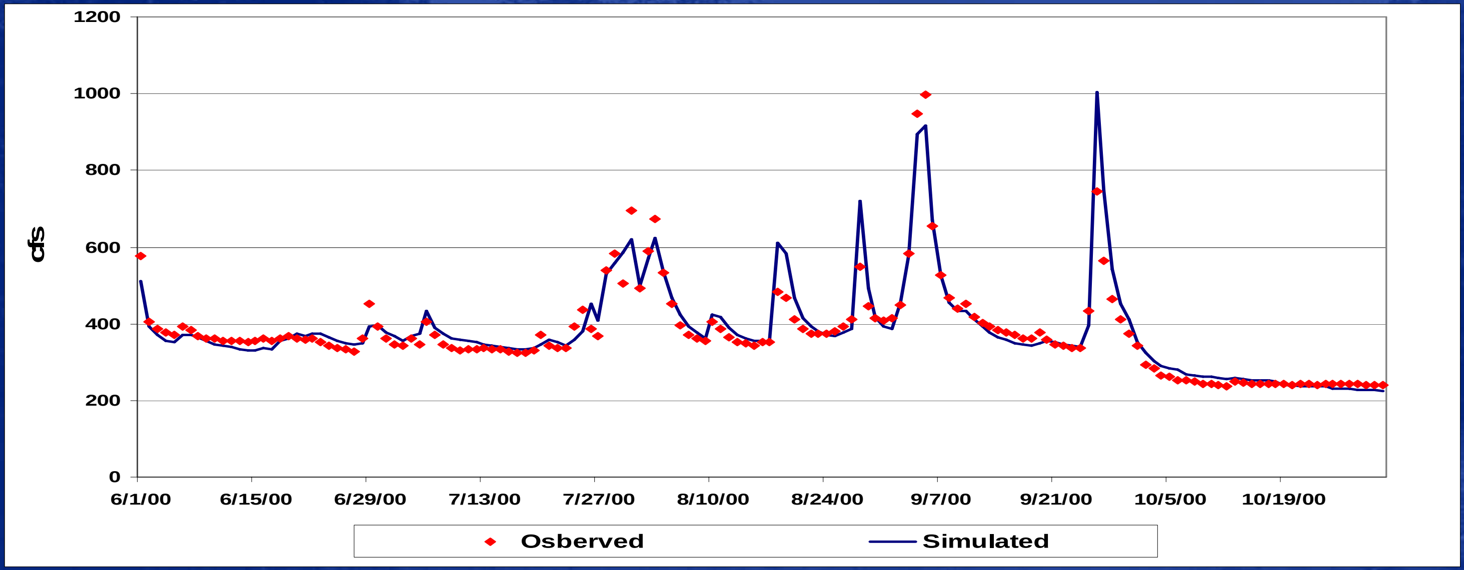


Jackson River Model Boundaries

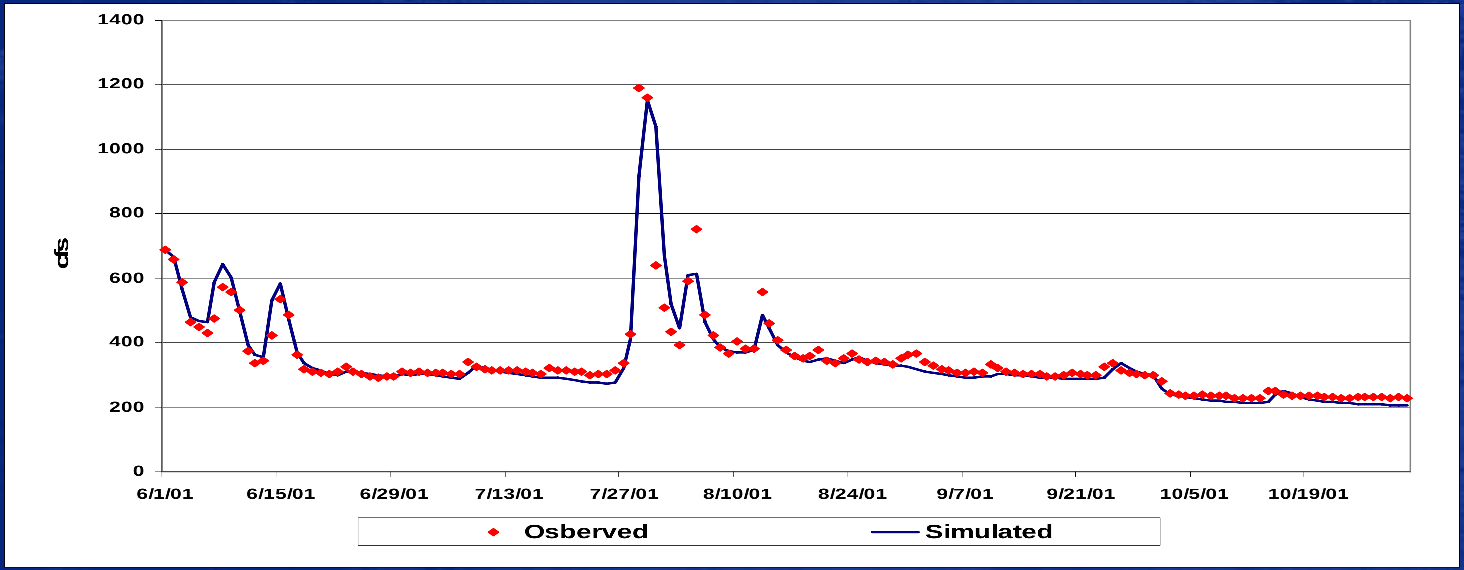
Seven boundaries are defined:

- Headwater located upstream of Filtration Plant
- Two major tributaries (Dunlap and Potts Creek)
- Four point source dischargers
  - MeadWestvaco
  - Covington City STP
  - Clifton Forge City STP
  - Allegheny WWTP)

Stream Flow Modeling Results for 2000 and 2001 at City Park (USGS 020131000)



Flow for 2000



Flow for 2001

Periphyton Model Parameterization

WASP Periphyton Global Rates	
Benthic Algae D:C Ratio (mg Dry Weight/mg C)	9.47
Benthic Algae N:C Ratio (mg N/mg C)	0.132
Benthic Algae P:C Ratio (mg P/mg C)	0.021
Benthic Algae Chl a:C Ratio (mg Chlorophyll a / mg C)	0.025
Benthic Algae O2:C Production (mg O2/mg C)	2.7
Growth Model, 0 = Zero Order; 1 = First Order	1
Max Growth Rate (gD/m2/d for 0-order growth, 1/d for 1-order growth)	0.88
Temp Coefficient for Benthic Algal Growth	1.068
Carrying Capacity for First Order Model (gD/m2)	500
Respiration Rate Constant (1/day)	0.1
Temperature Coefficient for Benthic Algal Respiration	1.1
Internal Nutrient Excretion Rate Constant for Benthic Algae (1/day)	0.06
Temperature Coefficient for Benthic Algal Nutrient Excretion	1.06
Death Rate Constant (1/day)	0.1
Temperature Coefficient for Benthic Algal Death	1.07

WASP 7.2 Periphyton Model Parameterization

WASP Periphyton Global Rates	
Half Saturation Uptake Constant for Extracellular Nitrogen (mg N/L)	0.15
Half Saturation Uptake Constant for Extracellular Phosphorus (mg P/L)	0.2
Inorganic Carbon Half-Saturation Constant (not implemented) (moles/L)	0.005
LIGHT OPTION, 1=Half saturation, 2=SMITH, 3= STEELE	2
Light Constant for growth (langleys/day)	135
Benthic Algae ammonia preference (mg N/L)	0.03
Minimum Cell Quota of Internal Nitrogen for Growth (mgN/gDW)	4
Minimum Cell Quota of Internal Phosphorus for Growth (mgP/gDW)	0.6
Maximum Nitrogen Uptake Rate for Benthic Algae (mgN/gDW-day)	52.798
Maximum Phosphorus Uptake Rate for Benthic Algae (mgP/gDW-day)	19.007
Half Saturation Uptake Constant for Intracellular Nitrogen (mgN/gDW)	7.603
Half Saturation Uptake Constant for Intracellular Phosphorus (mgP/gDW)	0.422

Calibration Results (June - October 2001)

The calibration is based on:

- Extensive availability of observed data for the model input:
  - Nutrient time series for all point sources and headwaters
  - Time functions for temperature, light extinction coefficient, and solar radiation
- Extensive availability of observed instream data for periphyton and nutrients for model evaluation

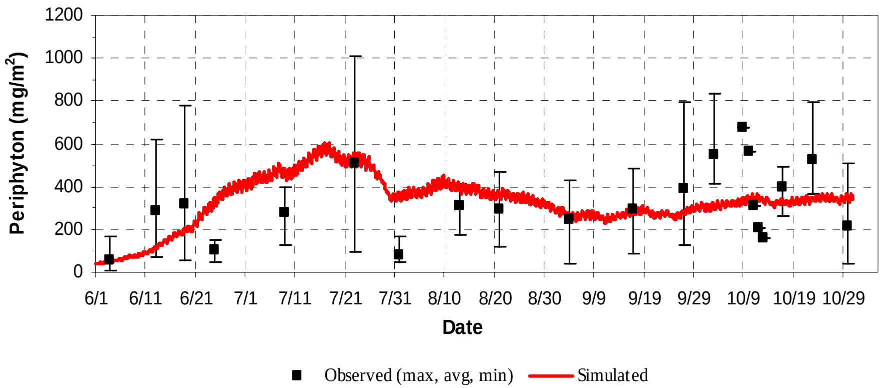
Results are presented as

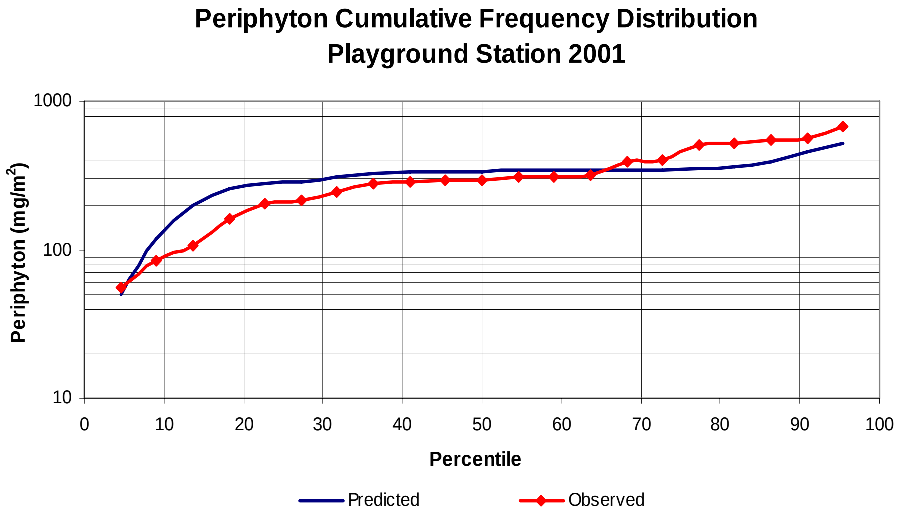
1. Graphical comparison between simulated and observed instream concentration (except for DO)
2. Tabular comparison between average simulated and observed instream periphyton concentration
3. Statistical comparison using cumulative distribution functions (CDFs)

Simulation Results (Calibration 2001) Temporal Periphyton and CDF

2001 Periphyton at Playground Station

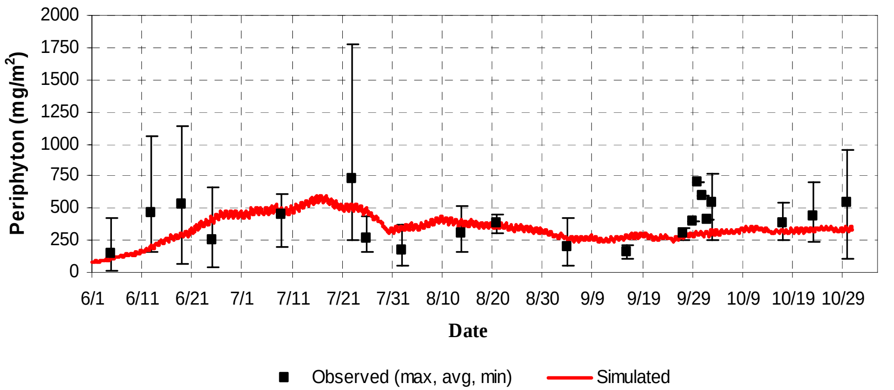
mg/m²	Jun	Jul	Aug	Sept	Oct	Season
obs	192	395	229	309	400	323
Sim	186	481	368	273	332	329

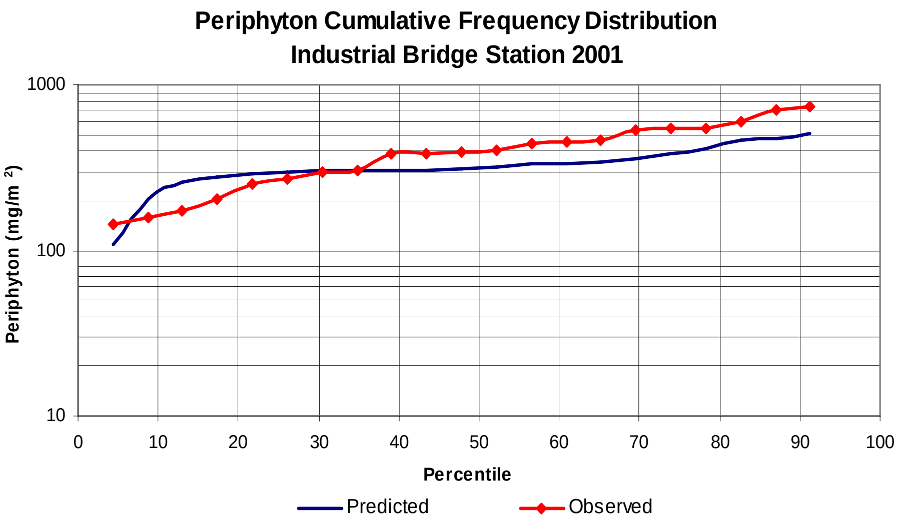




2001 Periphyton at Industrial Park Station

mg/m²	Jun	Jul	Aug	Sept	Oct	Season
obs	349	483	286	353	486	399
Sim	259	481	361	273	326	341

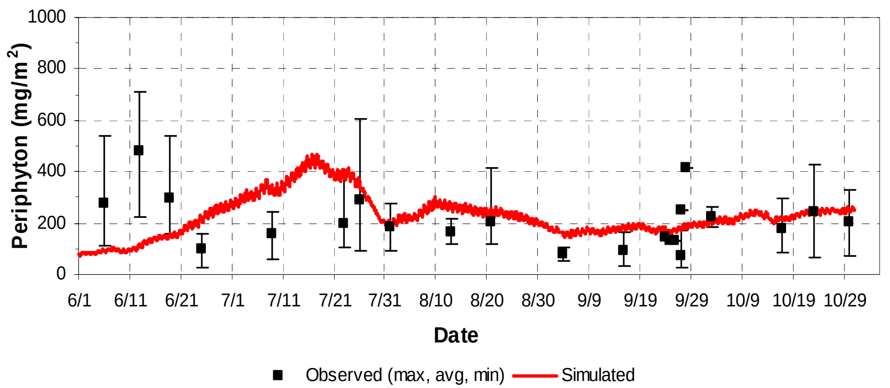




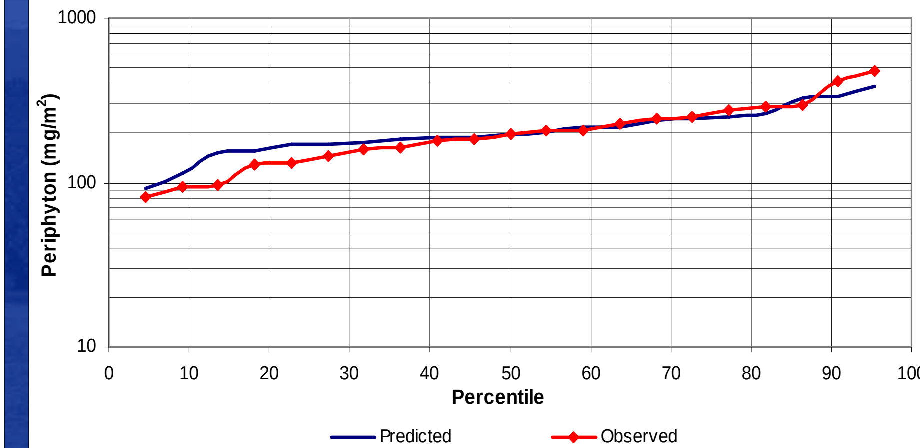
Simulation Results (Calibration 2001)
Temporal Periphyton and CDF

2001 Periphyton at Mallow Mall Station

mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	286	216	185	172	210	206
Sim	149	344	236	175	228	227

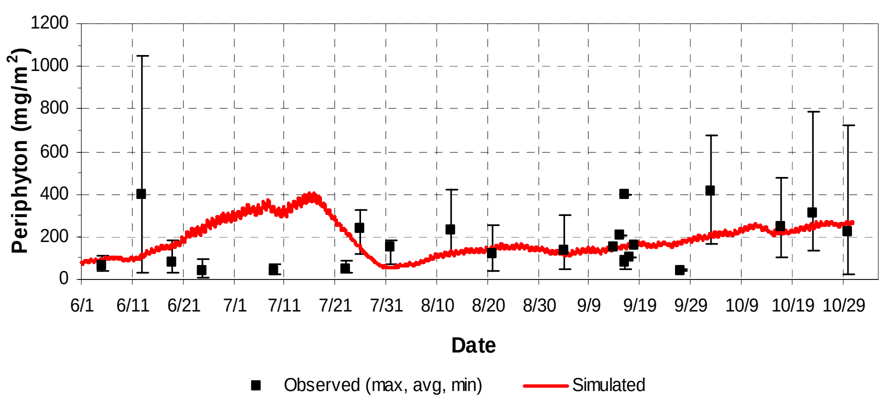


Periphyton Cumulative Frequency Distribution
Mallow Mall Station 2001

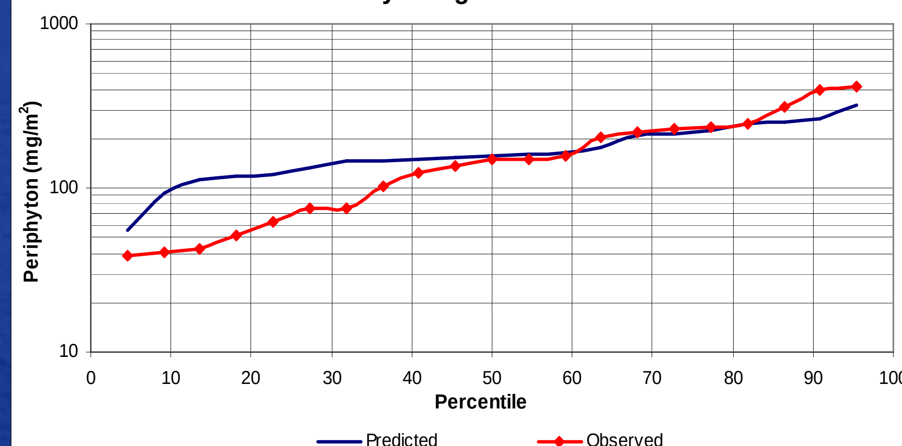


2001 Periphyton at Dabney Bridge Station

mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	144	109	166	187	260	176
Sim	160	268	120	151	235	187



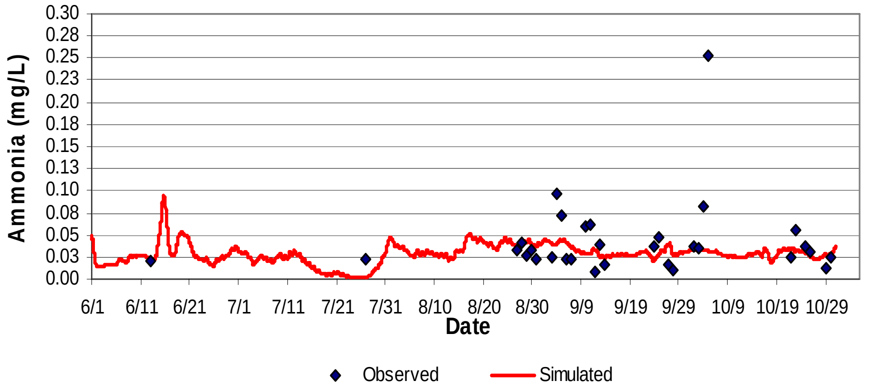
Periphyton Cumulative Frequency Distribution
Dabney Bridge Station 2001

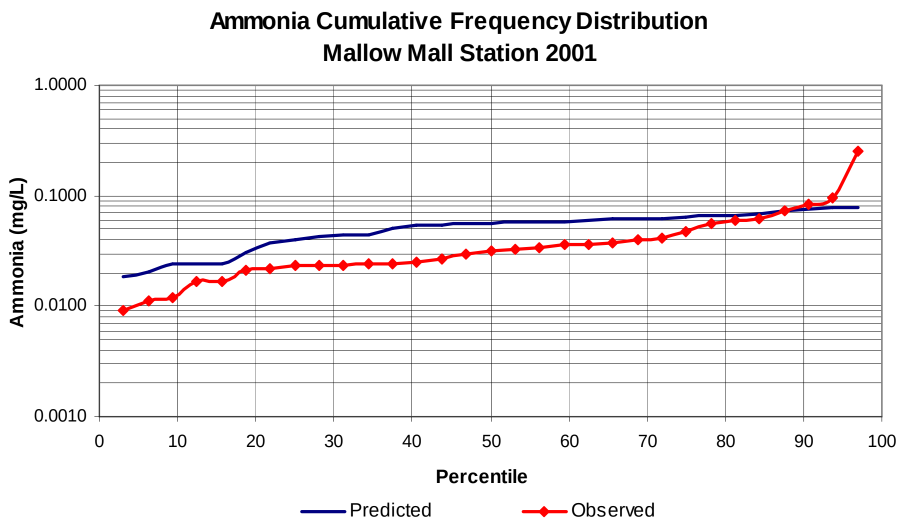


Simulation Results (Calibration 2001)
Temporal Nutrient and CDF

2001 Ammonia at Mallow Mall Station

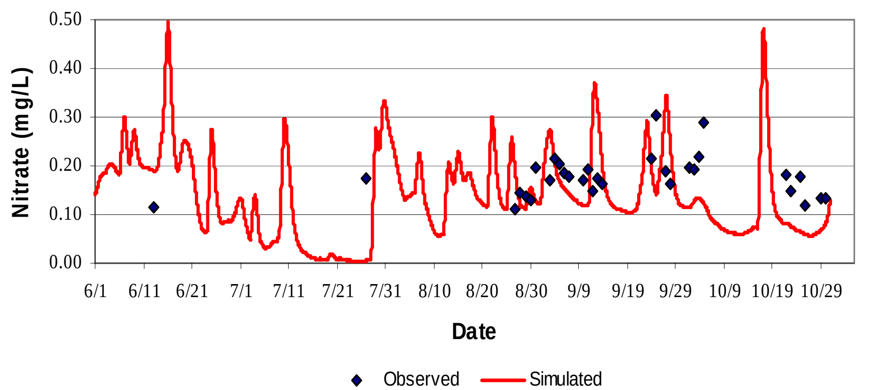
mg/L	Jun	Jul	Aug	Sept	Oct	Season
obs	0.021	0.023	0.031	0.038	0.059	0.043
Sim	0.029	0.016	0.036	0.032	0.029	0.028

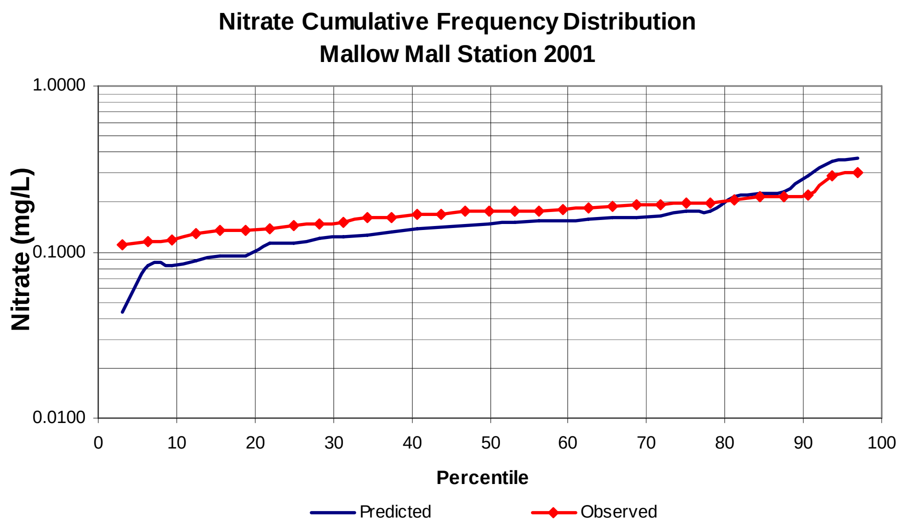




2001 Nitrate at Mallow Mall Station

mg/L	Jun	Jul	Aug	Sept	Oct	Season
obs	0.115	0.175	0.144	0.191	0.179	0.176
Sim	0.195	0.075	0.155	0.176	0.104	0.140

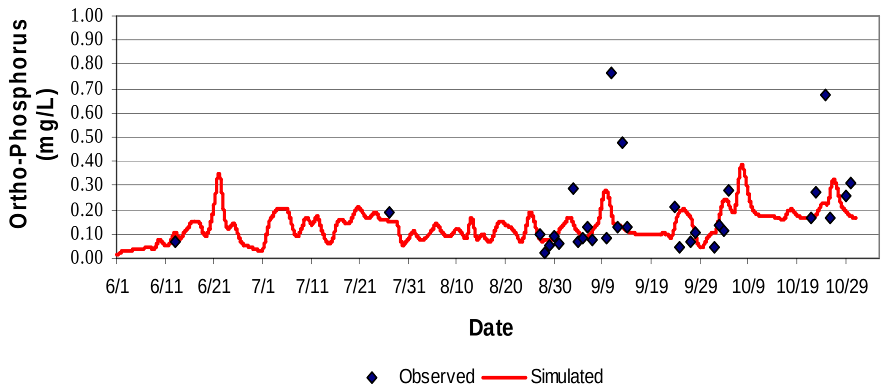




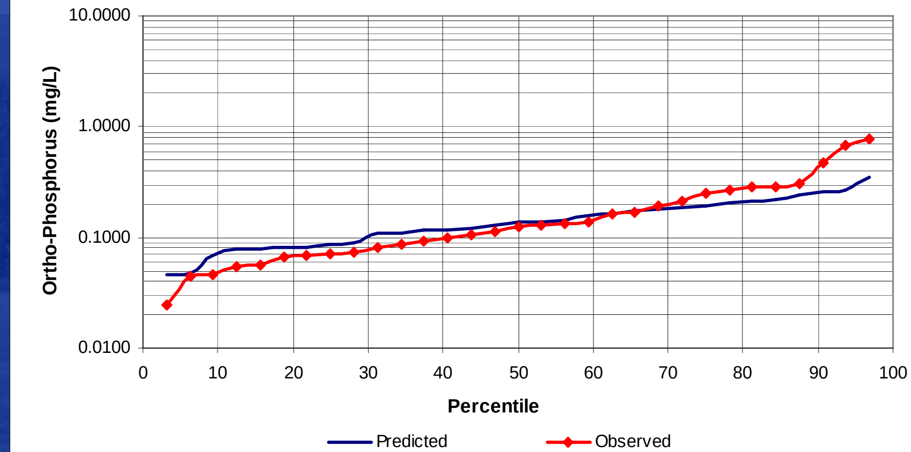
Simulation Results (Calibration 2001) Temporal Nutrient and CDF

2001 Ortho-Phosphorus at Mallow Mall Station

mg/L	Jun	Jul	Aug	Sept	Oct	Season
obs	0.069	0.191	0.031	0.190	0.242	0.183
Sim	0.093	0.144	0.108	0.129	0.204	0.135

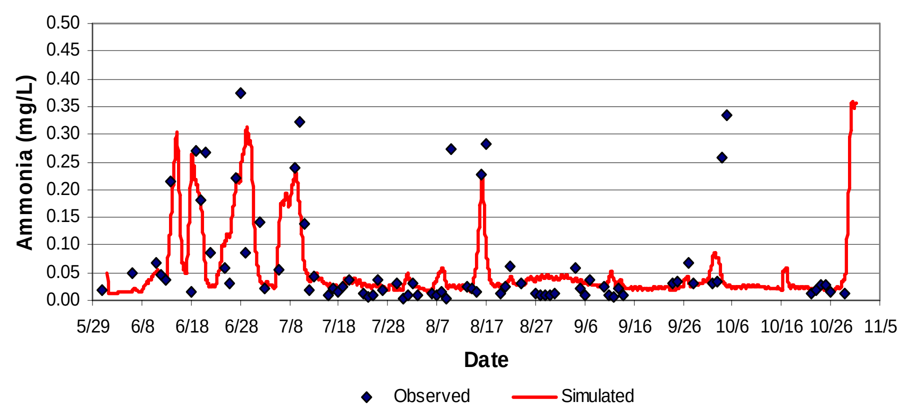


Ortho-Phosphorus Cumulative Frequency Distribution Mallow Mall Station 2001

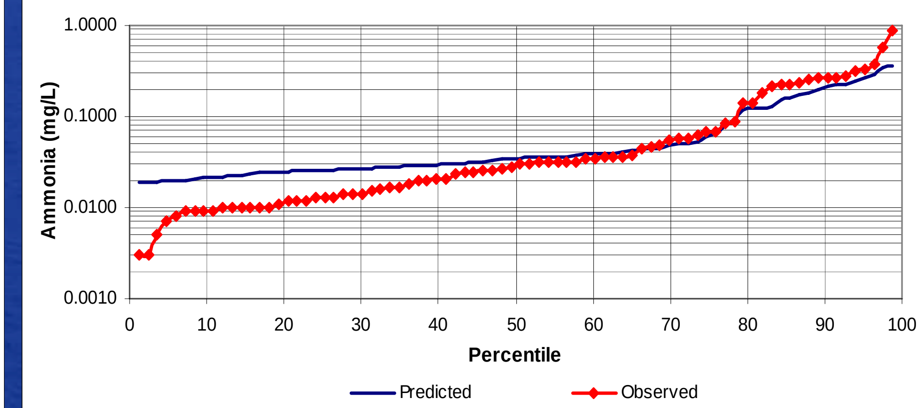


2001 Ammonia at Pedestrain Bridge Station

mg/L	Jun	Jul	Aug	Sept	Oct	Season
obs	0.134	0.060	0.051	0.028	0.184	0.084
Sim	0.102	0.056	0.040	0.029	0.045	0.054



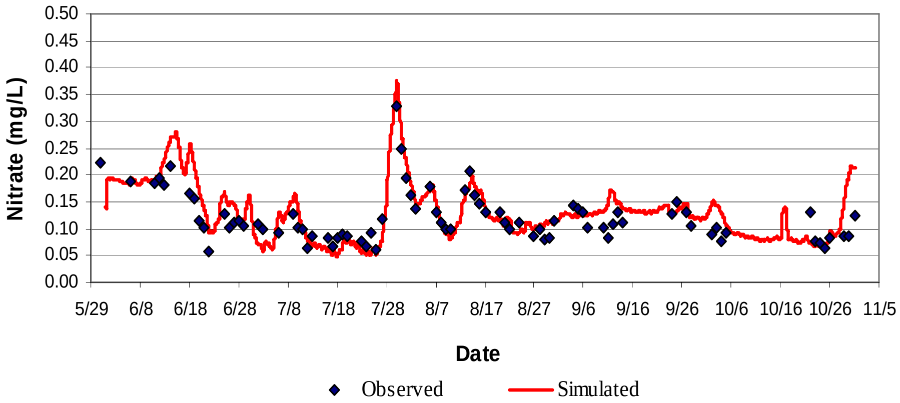
Ammonia Cumulative Frequency Distribution Pedestrian Bridge Station 2001



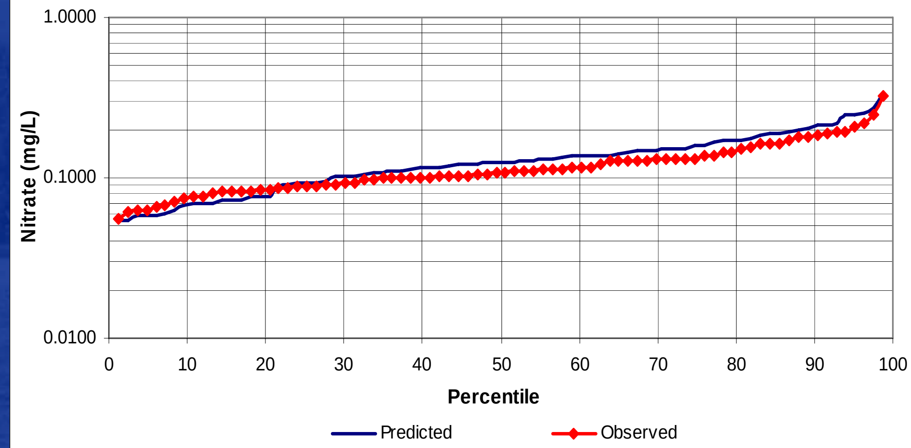
Simulation Results (Calibration 2001) Temporal Nutrient and CDF

2001 Nitrate at Pedestrain Bridge Station

mg/L	Jun	Jul	Aug	Sept	Oct	Season
obs	0.141	0.109	0.129	0.118	0.090	0.119
Sim	0.180	0.107	0.129	0.133	0.100	0.130

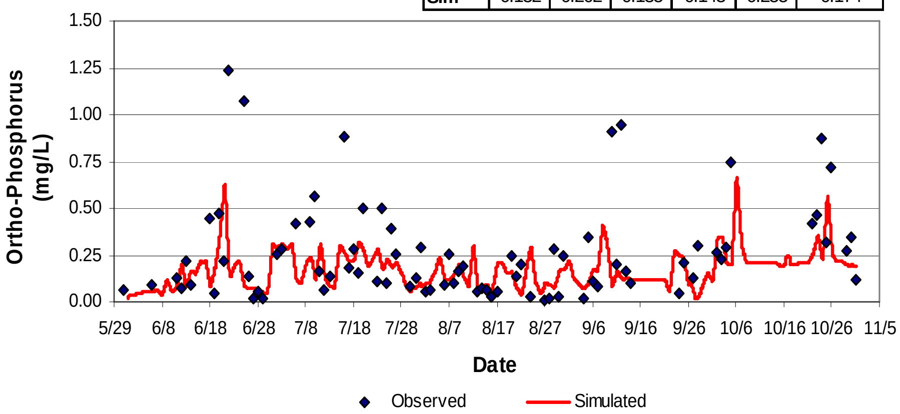


Nitrate Cumulative Frequency Distribution Pedestrian Bridge Station 2001

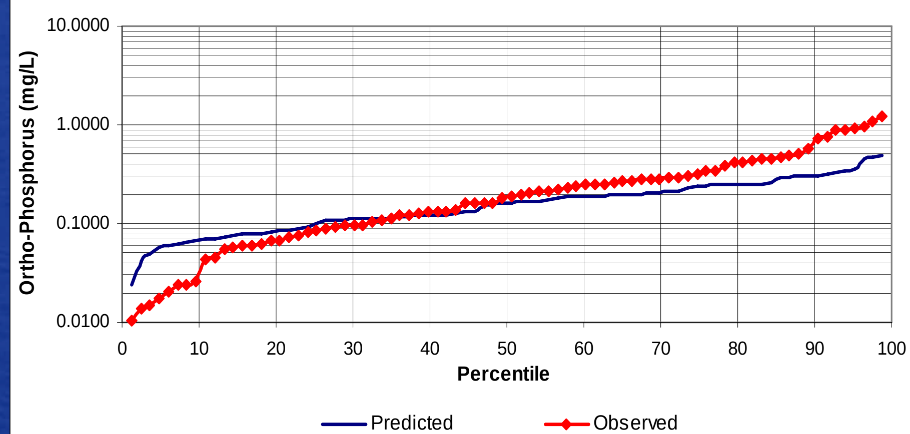


2001 Ortho-Phosphorus at Pedestrain Bridge Station

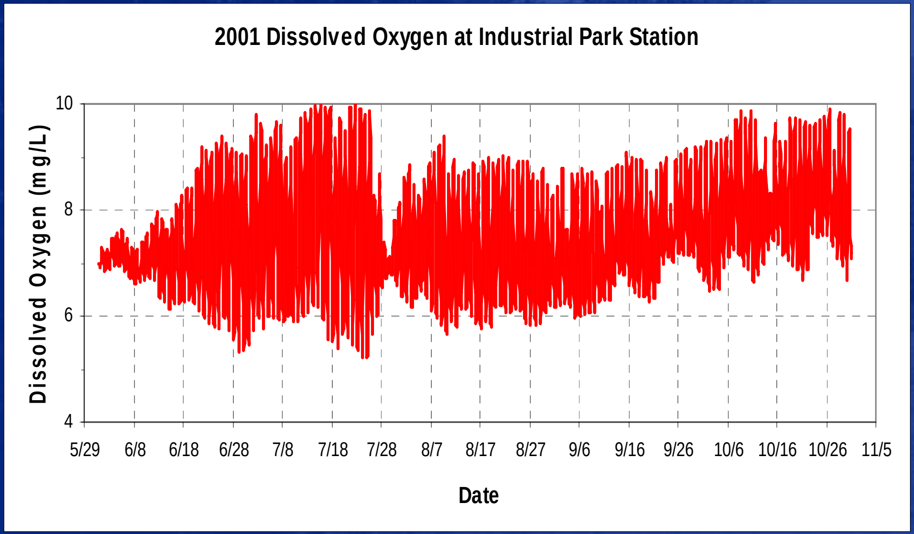
mg/L	Jun	Jul	Aug	Sept	Oct	Season
obs	0.288	0.294	0.122	0.274	0.421	0.262
Sim	0.132	0.202	0.135	0.143	0.255	0.174

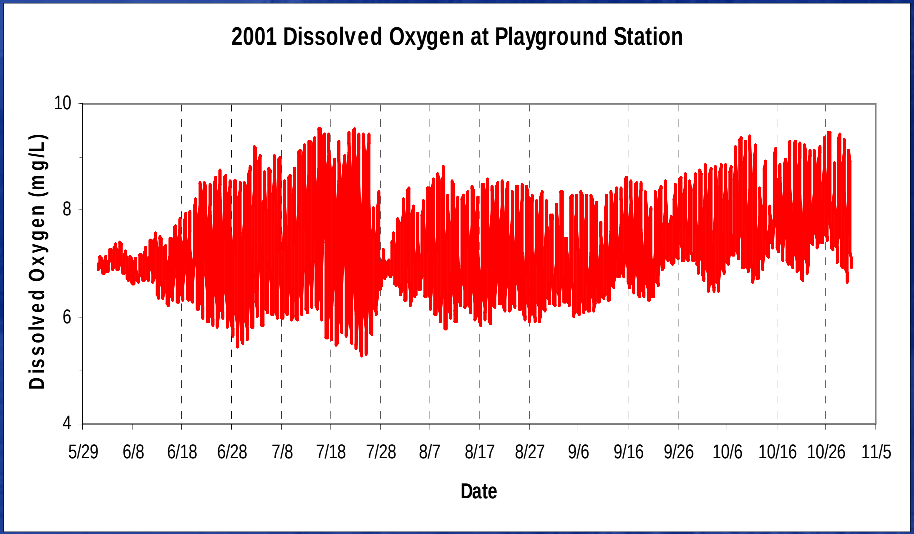


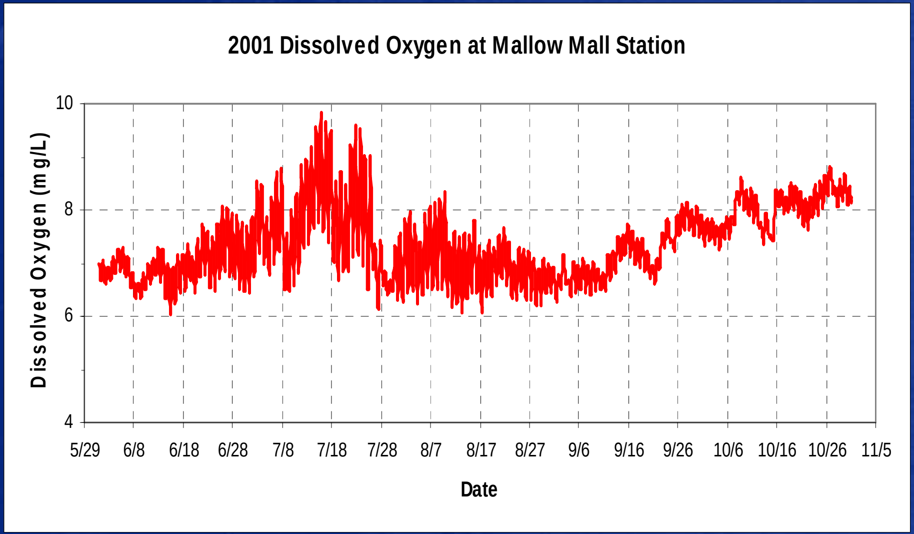
Ortho-Phosphorus Cumulative Frequency Distribution Pedestrian Bridge Station 2001



Simulation Results (Calibration 2001) Dissolved Oxygen







Validation Results

The validation is based on:

- Very limited observed data for the model input :
  - Constant observed load for all point sources
  - No observed data for headwaters
  - No observed time functions for temperature, light extinction coefficient, and solar radiation
- Reasonable availability of observed instream data for periphyton but very limited for nutrients

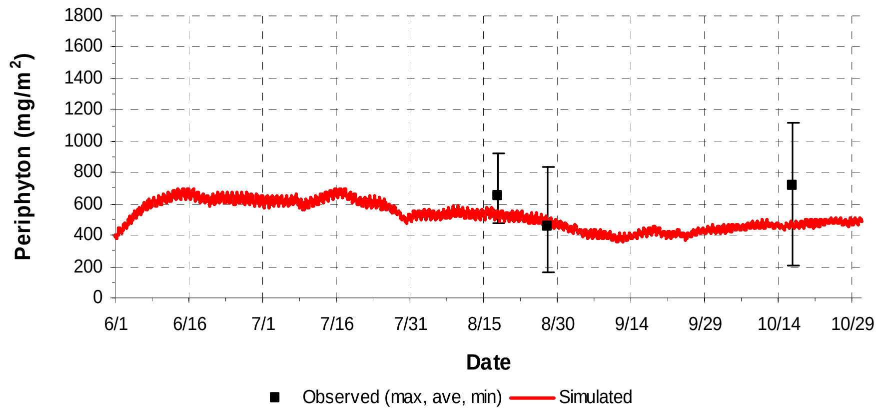
Results are presented as

1. Graphical comparison between simulated and observed instream concentration
2. Tabular comparison between average simulated and observed instream periphyton concentration
3. Statistical comparison using cumulative distribution functions (CDFs) only for periphyton

Simulation Results (Validation 2000) Temporal Periphyton and CDF

2000 Periphyton at Mill Bridge Station

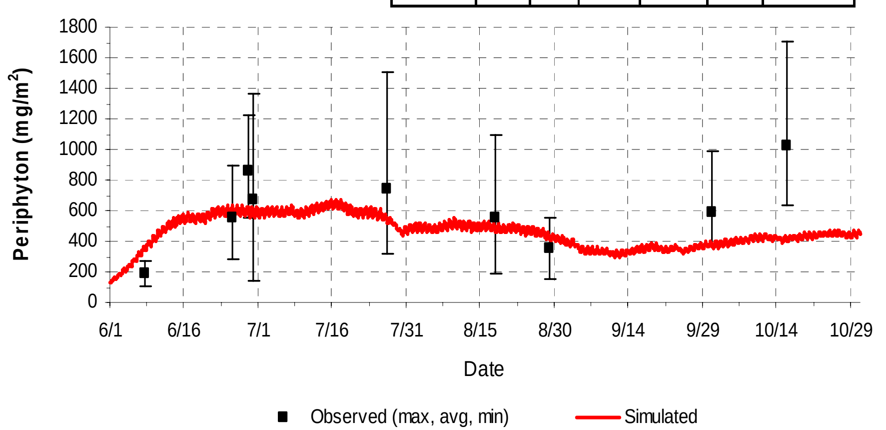
mg/m²	Jun	Jul	Aug	Sept	Oct	Season
obs	-	-	556	-	714	608
Sim	607	608	520	410	467	523

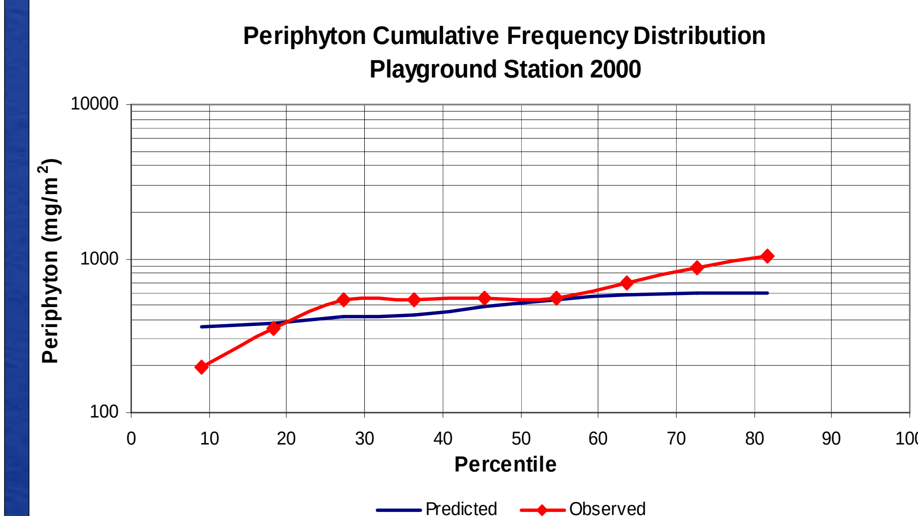


NO SUFFICENT OBSERVED DATA (3 DATA POINTS) TO DEVELOP THE CDF

2000 Periphyton at Playground Station

mg/m²	Jun	Jul	Aug	Sept	Oct	Season
obs	567	735	450	-	805	613
Sim	469	582	479	349	423	461

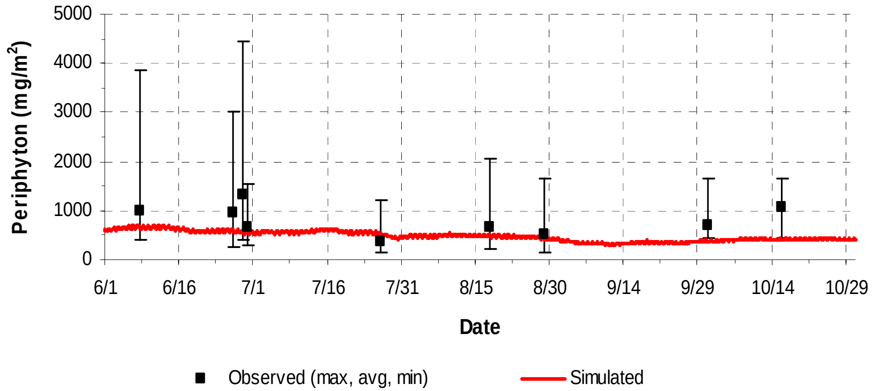




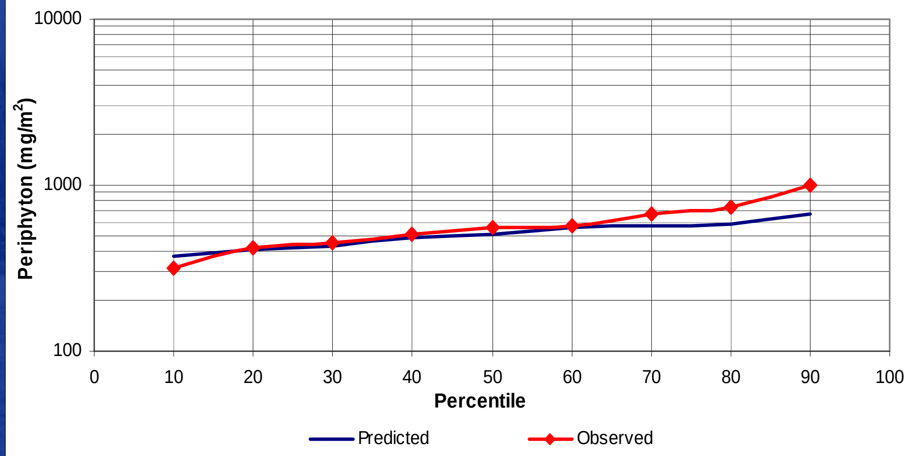
Simulation Results (Validation 2000)
Temporal Periphyton and CDF

2000 Periphyton at Industrial Park Station

mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	992	381	590	-	884	811
sim	616	550	474	349	411	480

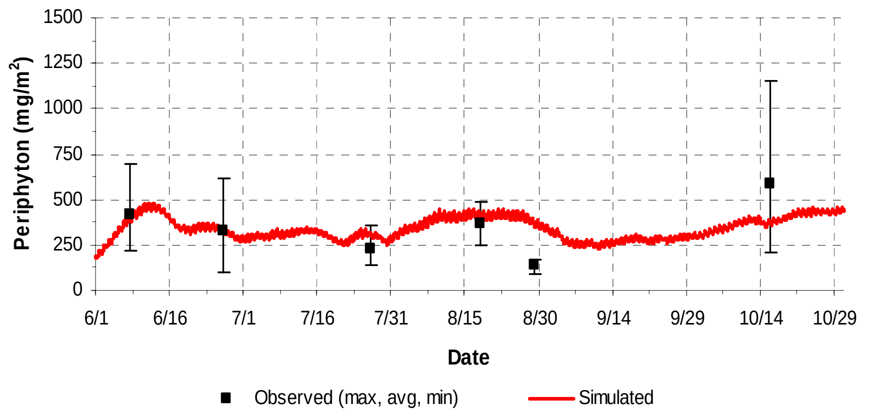


Periphyton Cumulative Frequency Distribution
Industrial Bridge Station 2001

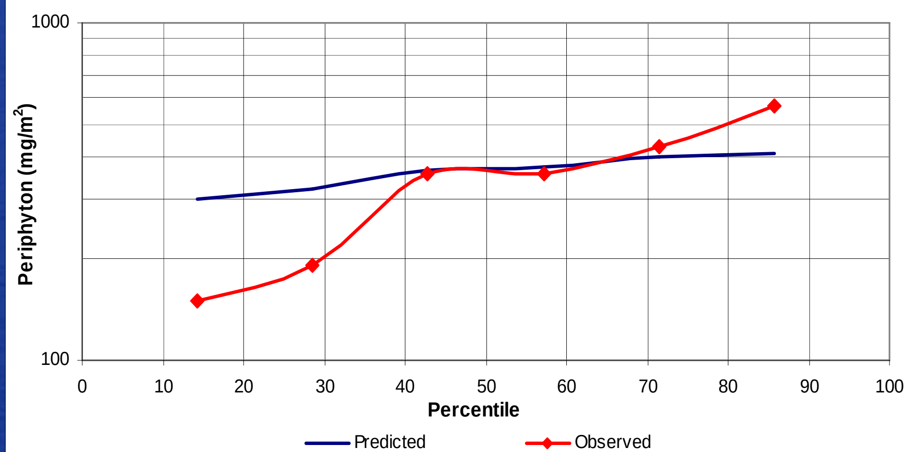


2000 Periphyton at Mallow Mall Station

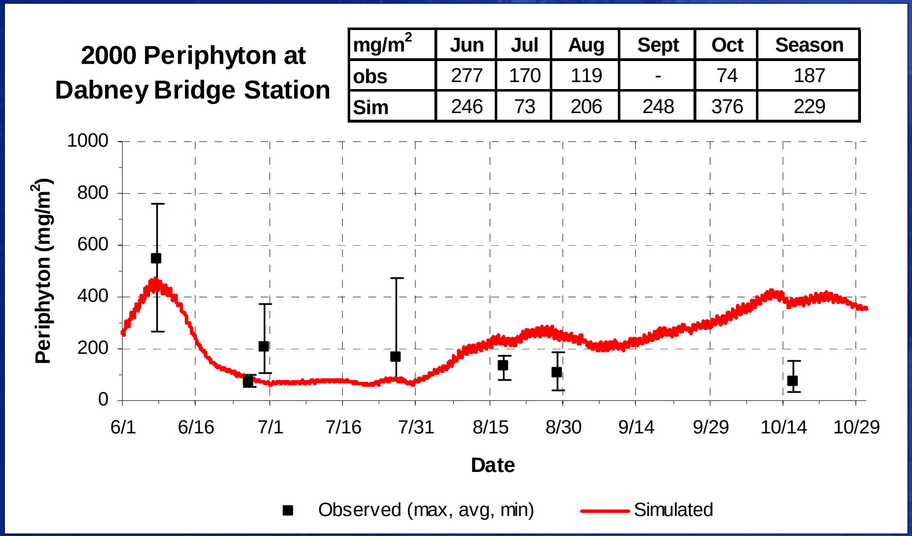
mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	371	228	254	-	586	344
Sim	351	300	390	277	385	341



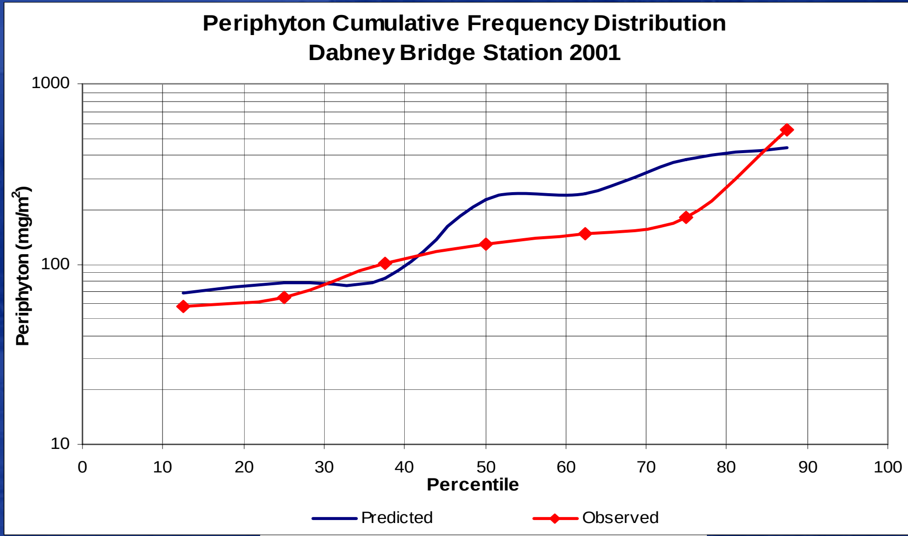
Periphyton Cumulative Frequency Distribution
Mallow Mall Station 2001



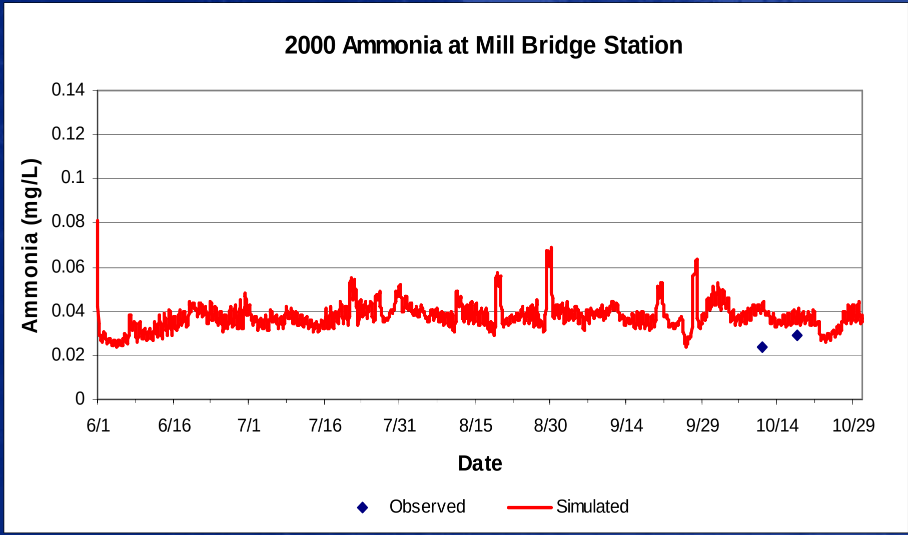
Simulation Results (Validation 2000)
Temporal Periphyton and CDF

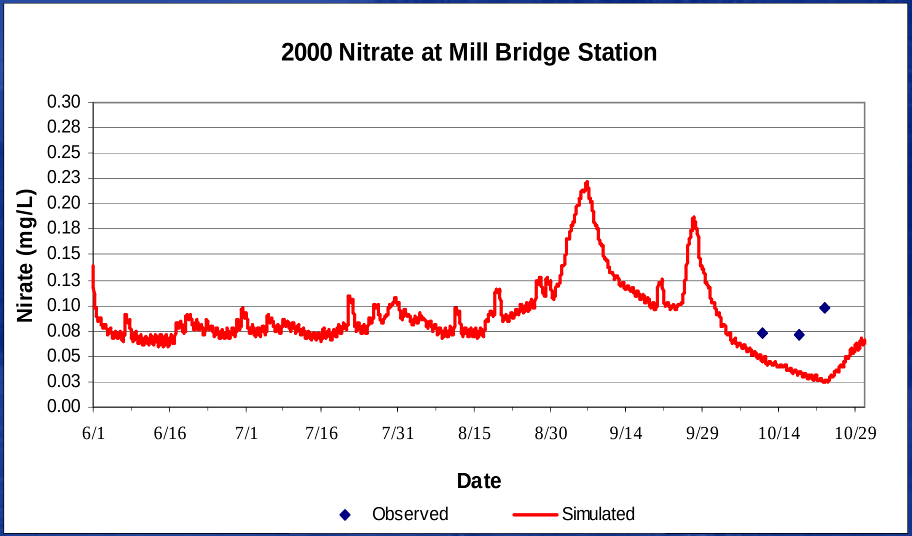


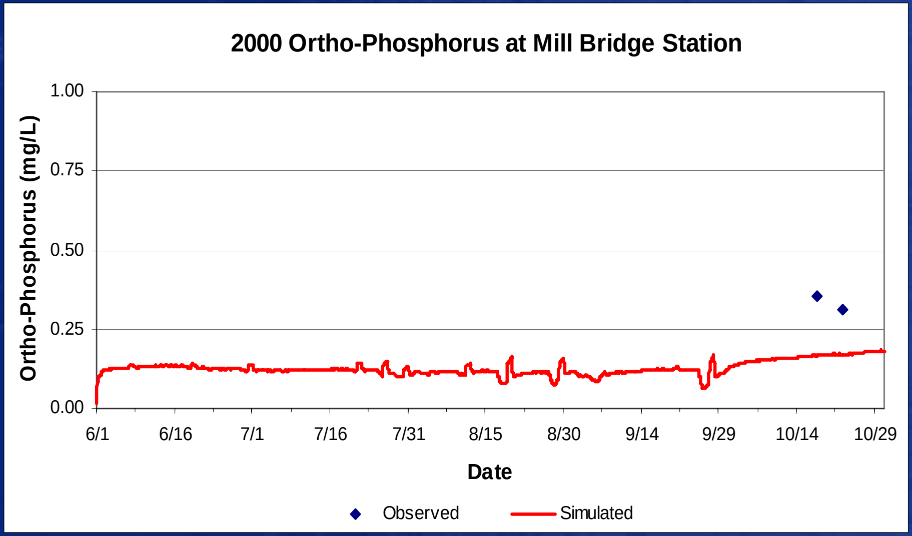
mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	277	170	119	-	74	187
Sim	246	73	206	248	376	229



Simulation Results at Mill Bridge Ammonia, NO3-N, PO4-P (Validation 2000)







PO4-P Point Source Contributions

Point Sources PO4-P June to October 2001				
Discharger	**Flow (MGD)**	**Average Discharge PO4-P (mg/L)**	**PO4-P Load June-October 2001 (lbs)**	**% Total Point Source Load**
MeadWestvaco	29.82	1.31	49,807	85.1%
Covington STP	1.79	1.15	2,630	4.5%
Clifton Forge STP	1.39	3.30	5,858	10.0%
Low Moor STP	0.16	1.15	228	0.4%
Total Point Sources			**57,759**	**100.00%**

Point Sources PO4-P June to October 2006				
Discharger	**Flow (MGD)**	**Average Discharge PO4-P (mg/L)**	**PO4-P Load June-October 2001 (lbs)**	**% Total Point Source Load**
MeadWestvaco	32.2	0.21	8,572	49.75%
Covington STP	1.79	1.15	2,610	15.15%
Clifton Forge STP	1.39	3.3	5,815	33.75%
Low Moor STP	0.16	1.15	233	1.35%
Total Point Sources			**17,230**	**100.00%**

PO4-P NPS Contributions

PO4-P NPS Contribution				
Period	**Point Sources (lbs)**	**Nonpoint Sources (lbs)**	**Total Load (lbs)**	**Nonpoint Source Load % of Total**
June- October 2000	46,298	1,639	47,937	3.42%
June-October 2001	57,759	1,226	58,985	2.08%
June-October 2006	17,288	1,930	19,218	10.04%
Average	**40.448**	**1.598**	**42,047**	5.18%

- Analysis of the point sources and nonpoint source contributions indicates that the Jackson River is an effluent-dominated stream
- Consequently, limits for PO4-P loads will be developed only for point sources

Current Conditions Scenario (2006)

- Calibration and validation of the WASP7 model focused on reproducing periphyton and nutrient observations during the 2000 and 2001 growing seasons.

- The calibrated model will be used to develop PO4-P allocations and to incorporate the potential periphyton scouring due to the flow-pulse releases from the Gathright Dam

- Year 2006 is selected for the current conditions scenario, since recent data was collected during the 2006 growing season as part of the pulse studies conducted by the ANS, MeadWestvaco, and VADEQ.

Current Conditions Scenario (2006)

The observed data for 2006 consist of:

- Instream periphyton measurements
- Nutrients measurements
- Observed effluent nutrient time series from discharger MeadWestvaco

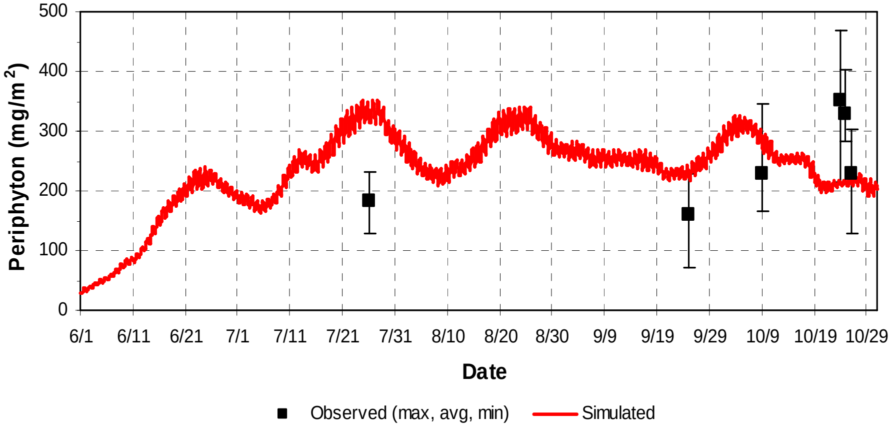
Results are presented as

1. **Graphical comparison between simulated and observed instream concentration**
2. **Tabular comparison between average simulated and observed instream periphyton concentration**

Simulation Results (Current Condition 2006)
Periphyton

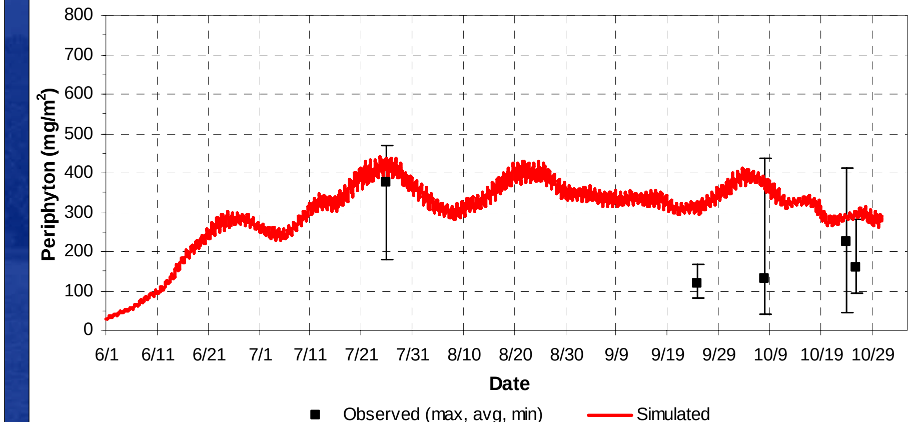
2006 Periphyton at Playground Station

mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	-	184	-	160	284	247
Sim	137	257	272	250	250	234



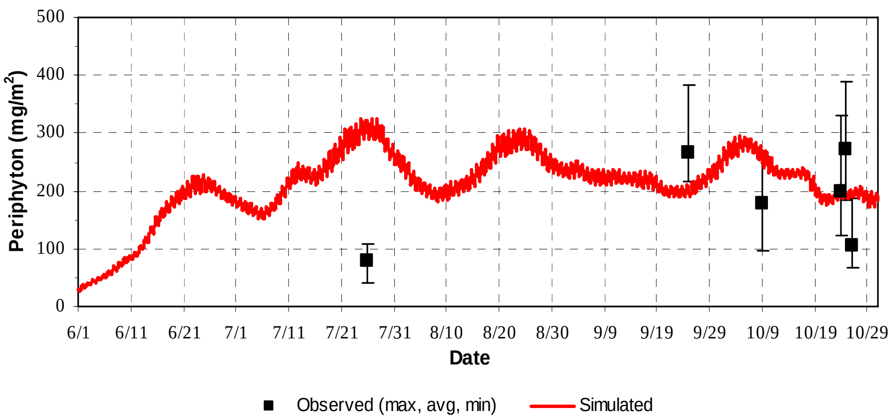
2006 Periphyton at Mill Bridge Station

mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	-	376	-	117	171	201
Sim	168	334	353	331	326	303



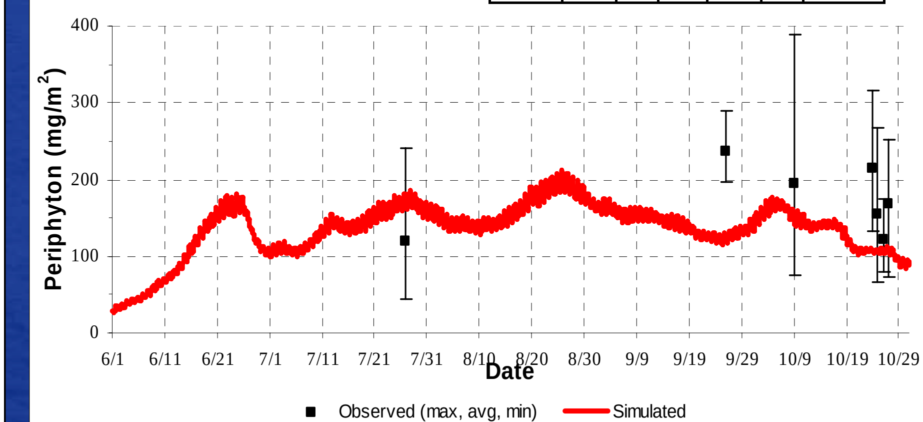
2006 Periphyton at Industrial Park Station

mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	-	78	-	267	204	183
Sim	133	236	240	219	226	211



2006 Periphyton at Mallow Mall Station

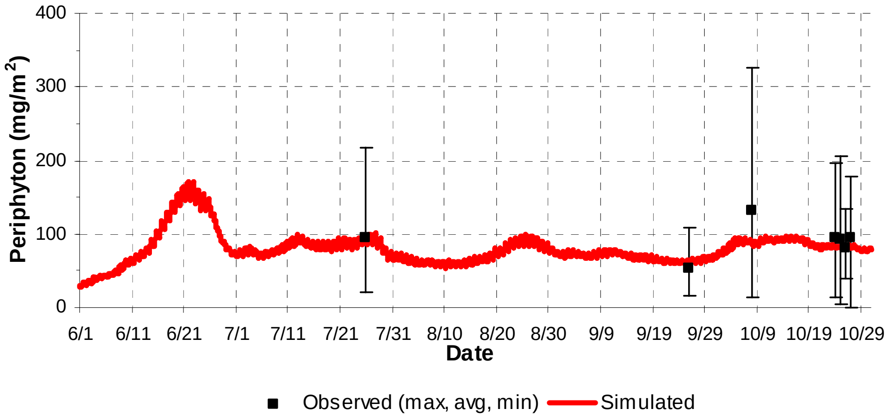
mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	-	119	-	236	170	172
Sim	100	140	163	143	131	136



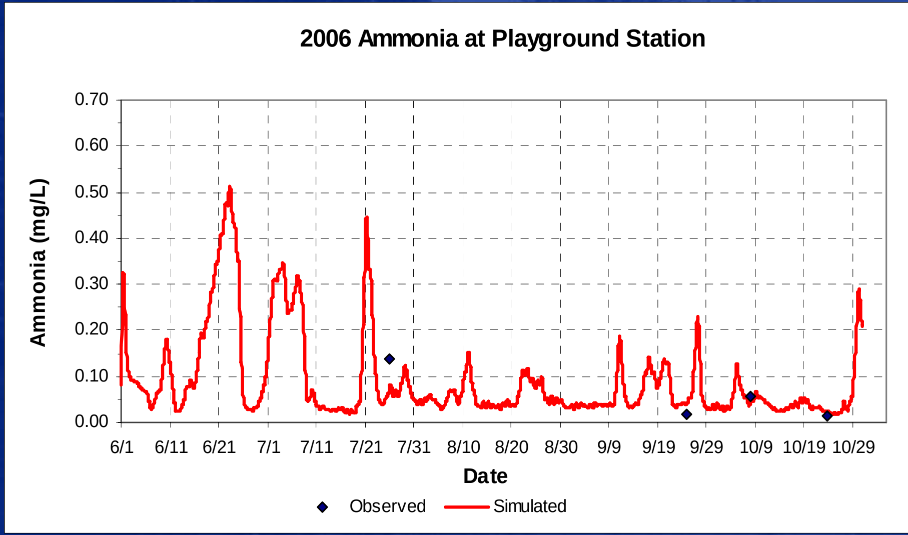
Simulation Results (Current Condition 2006) Periphyton

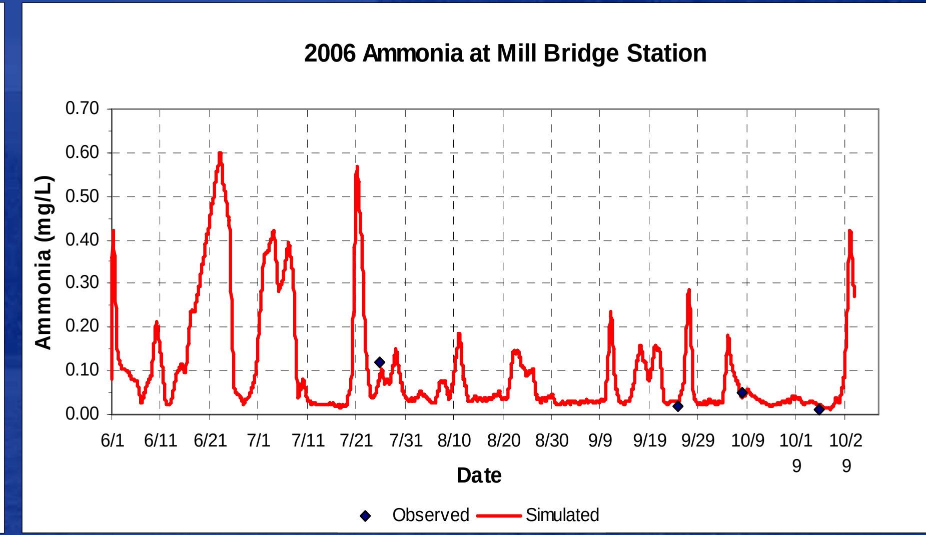
2006 Periphyton at Dabney Bridge Station

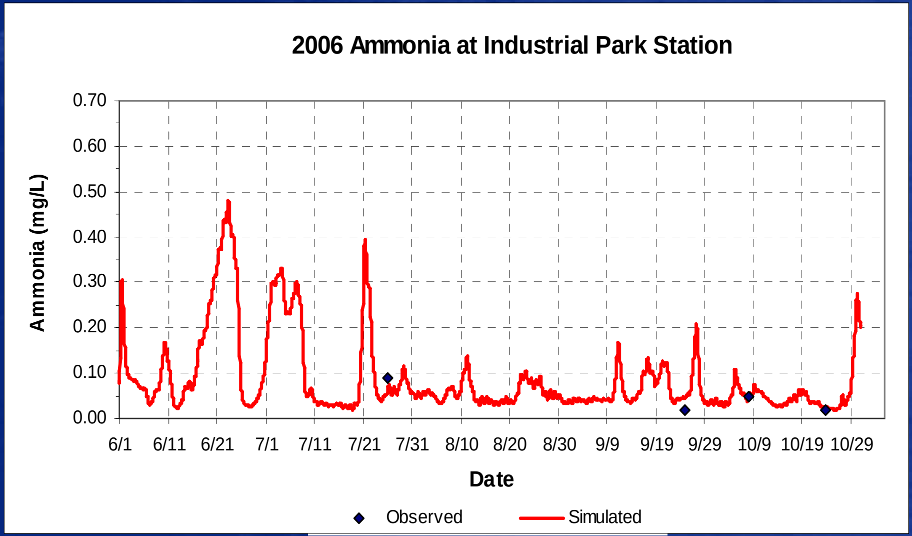
mg/m^2	Jun	Jul	Aug	Sept	Oct	Season
obs	-	95	-	54	99	92
Sim	90	82	71	69	86	80

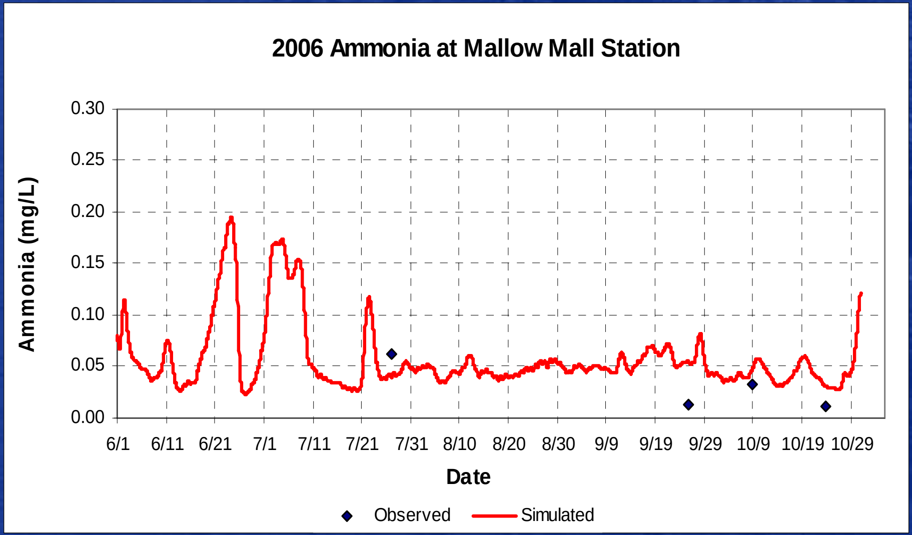


Simulation Results (Current Condition 2006) Ammonia

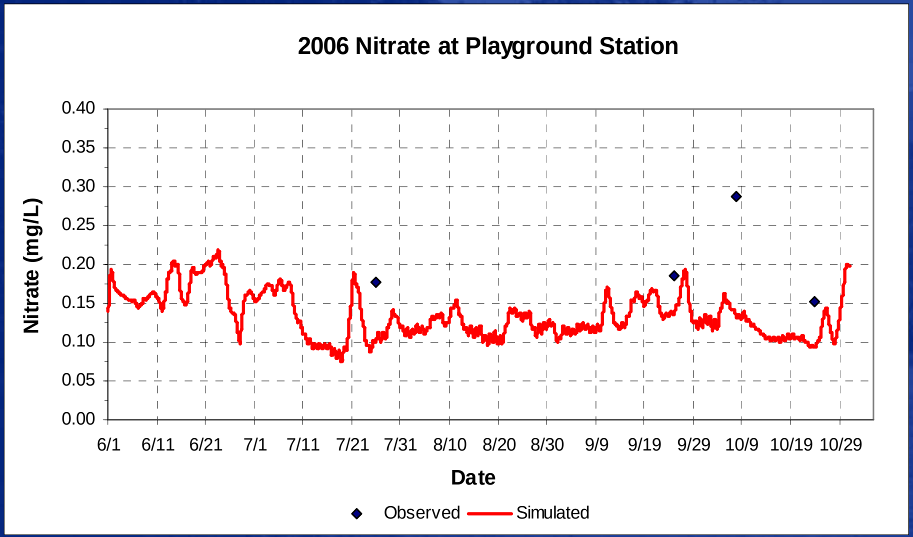


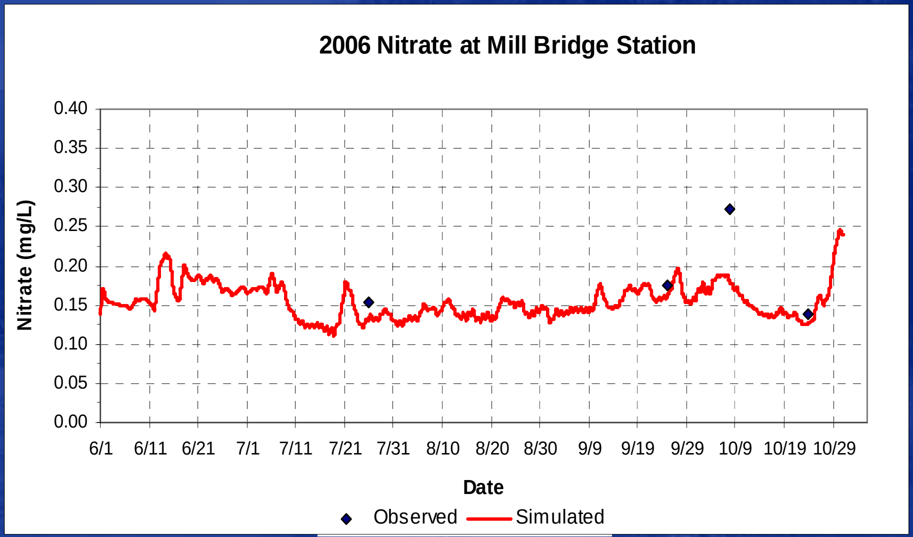


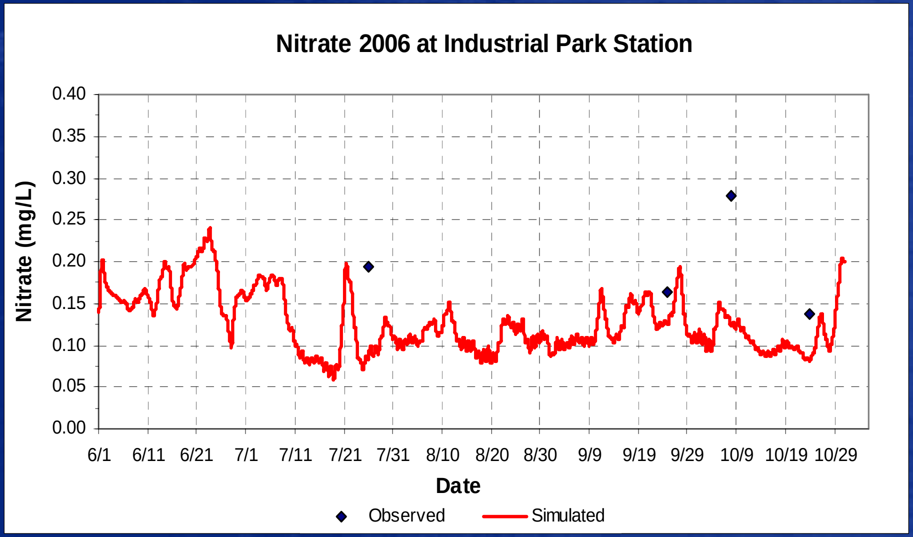


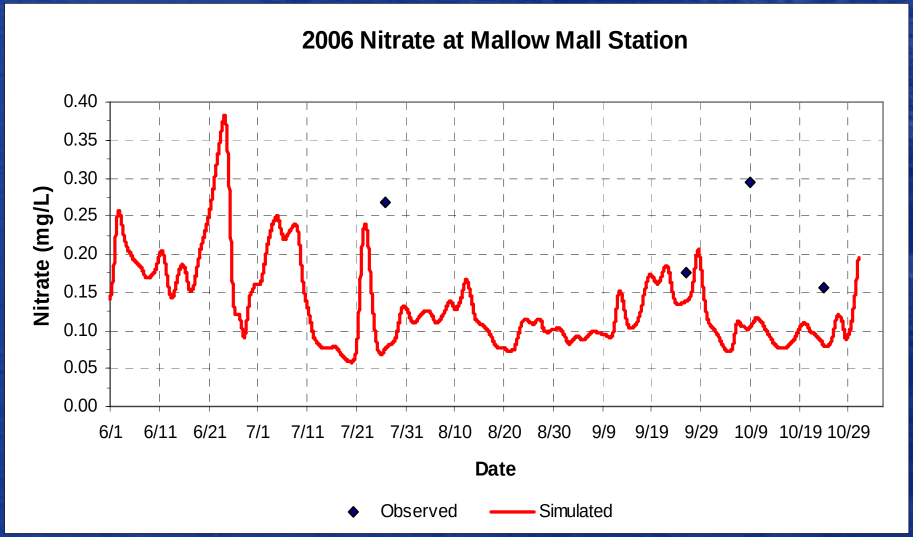


Simulation Results (Current Condition 2006) Nitrate

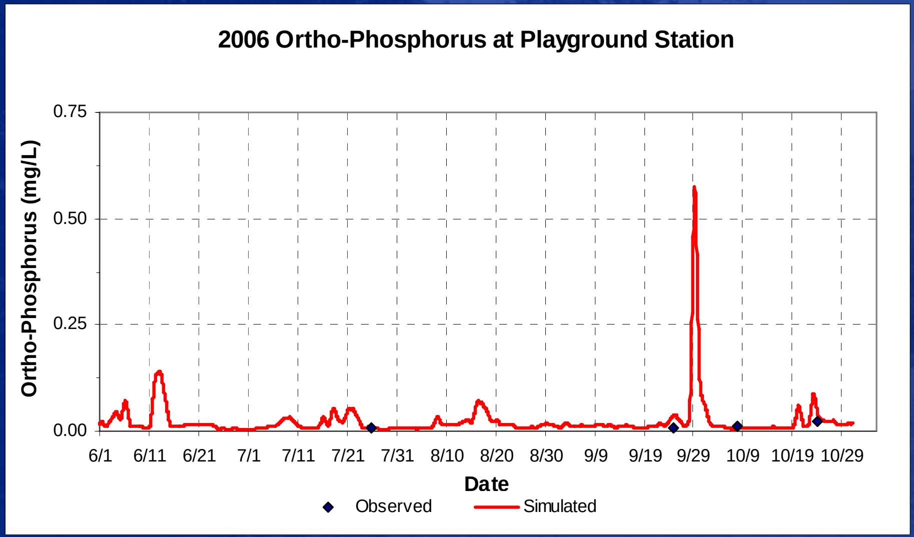


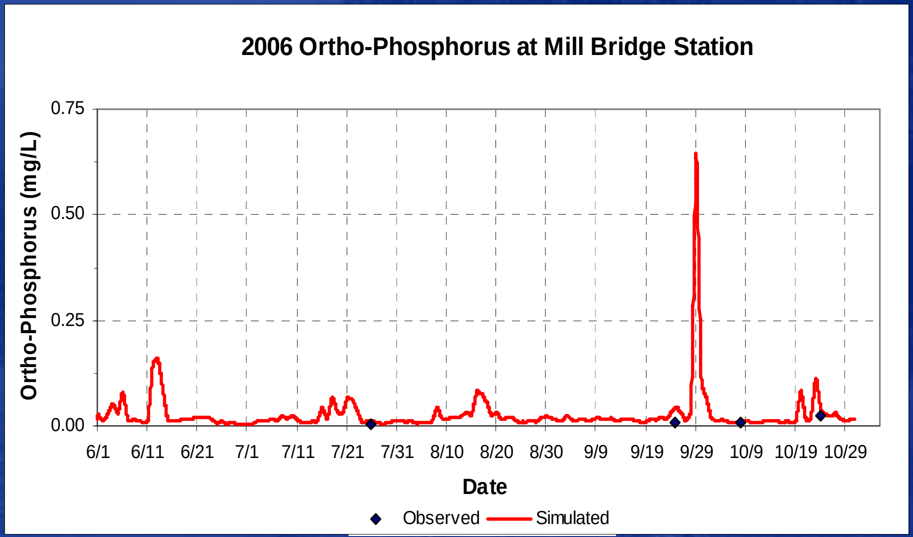


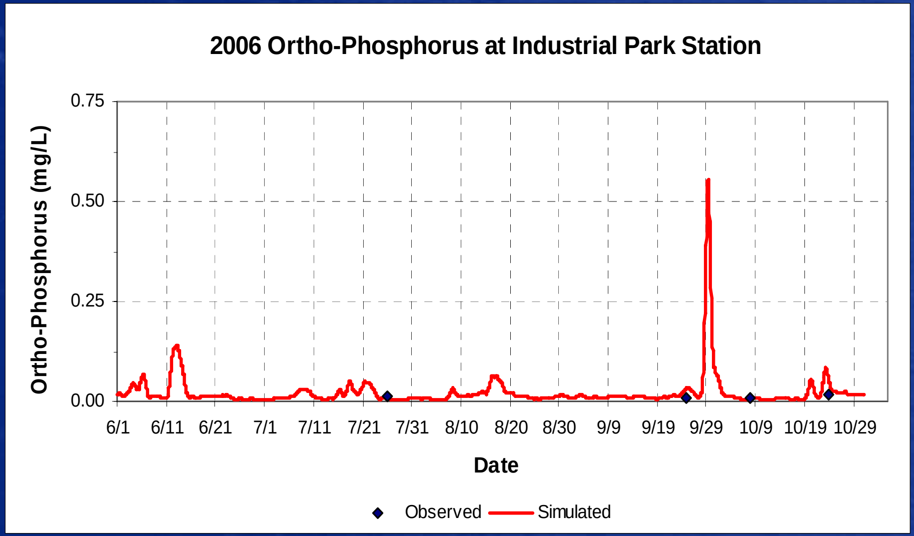


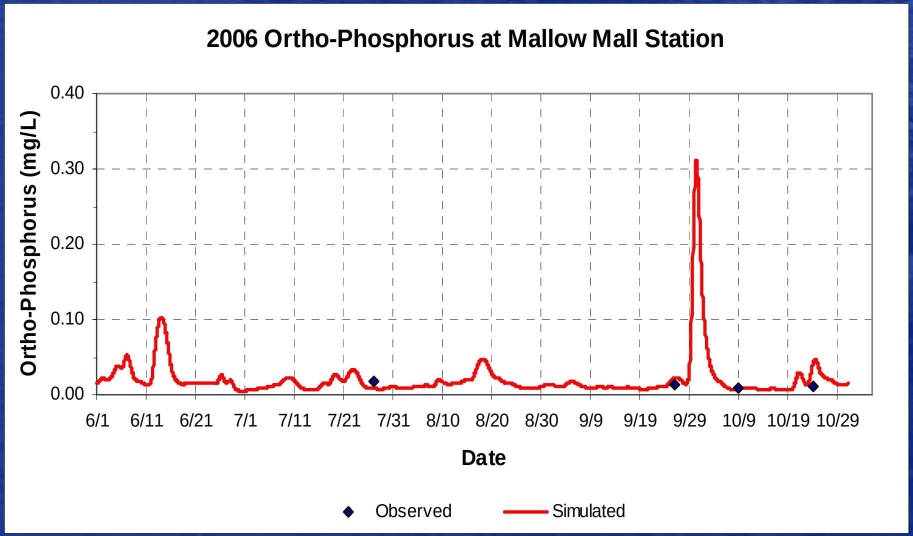


Simulation Results (Current Condition 2006) Ortho-Phosphorous









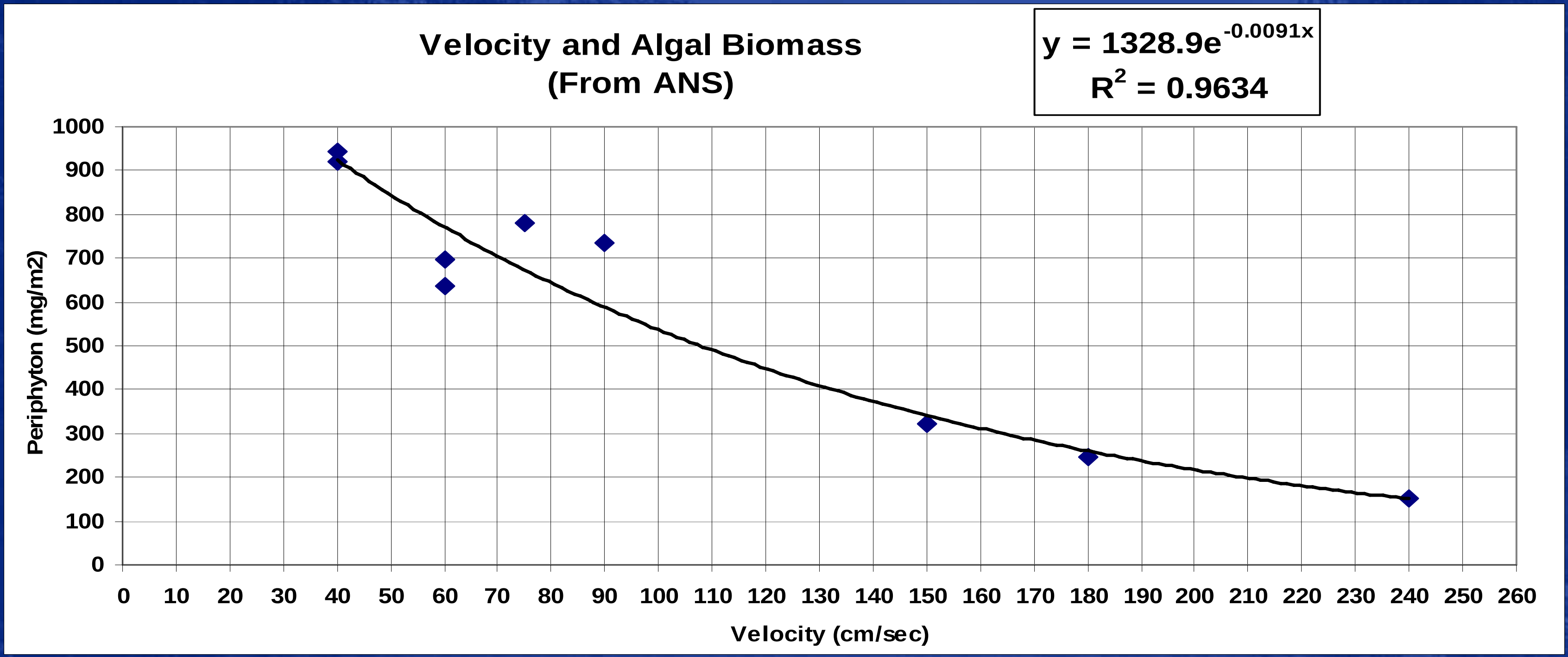
Allocation Strategy

Variables to consider when developing PO4-P allocations

1. Existing periphyton and phosphorus levels in the Jackson River (2006)
2. Existing point sources phosphorus discharge levels
3. Phosphorus concentration to be assigned to point sources
4. Amount of periphyton that can be potentially scoured by the flow-pulses

The combination of all these variables should result to an average periphyton concentration of 100 mg/m^2 in the Jackson River.

Velocity and Periphyton

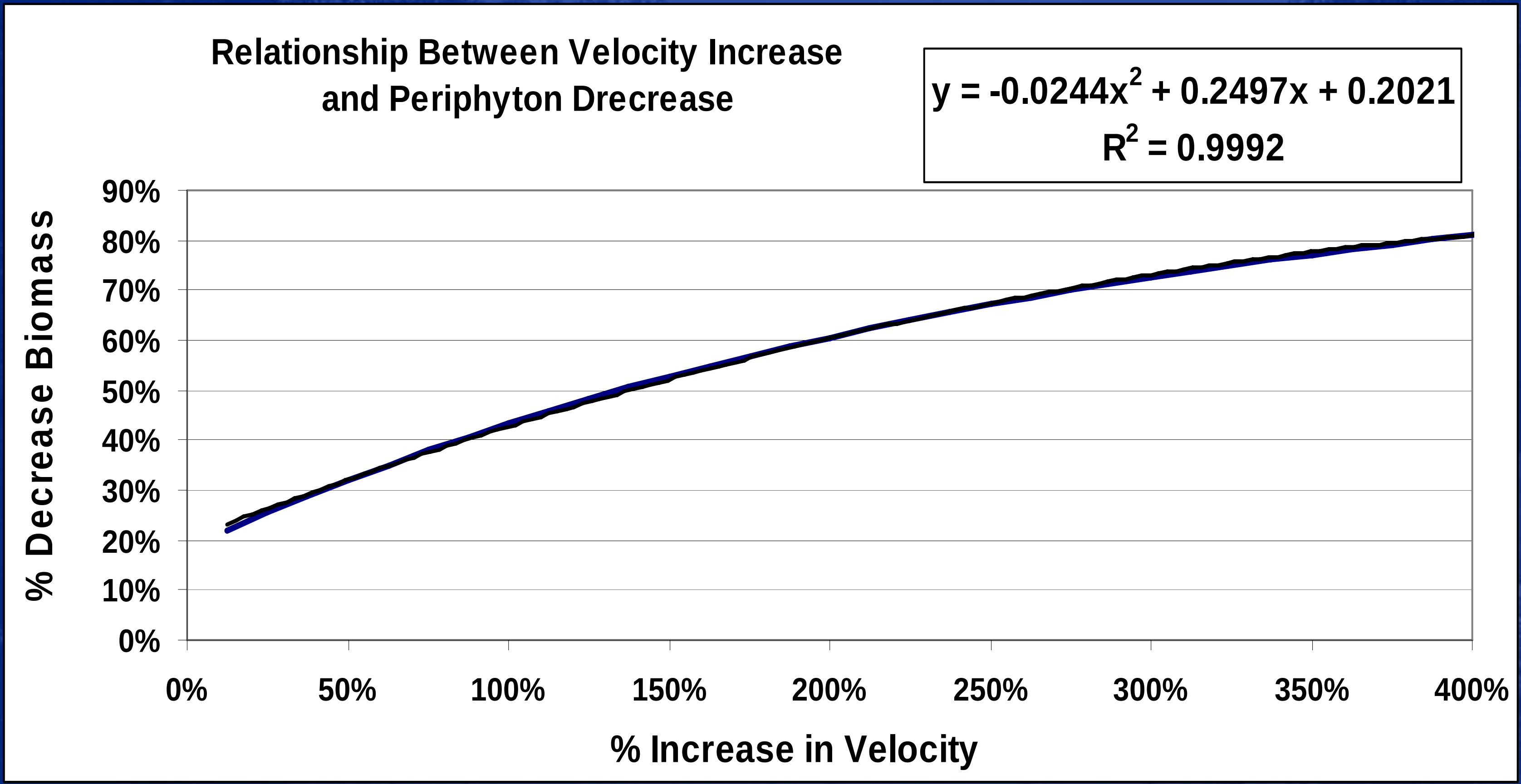


This relationship cannot be used directly to estimate the periphyton removal as a function of a specific velocity

The amount of periphyton removed is dependent of the initial biomass level

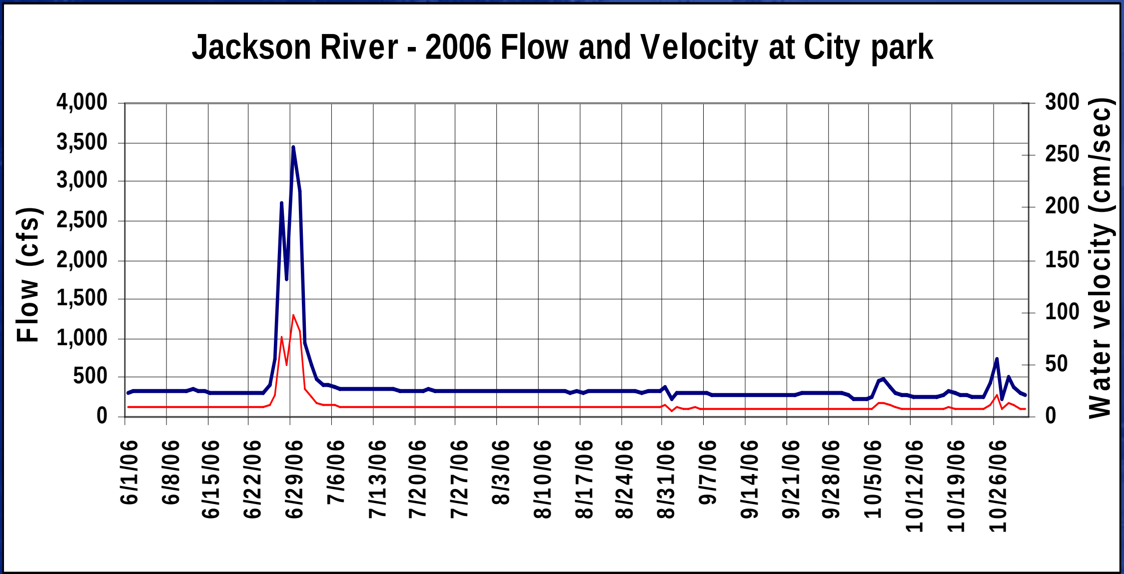
This equation is used to develop a dimensionless relationship that presents the results in terms of “velocity-increase” and “periphyton-decrease”

Modeling Strategy

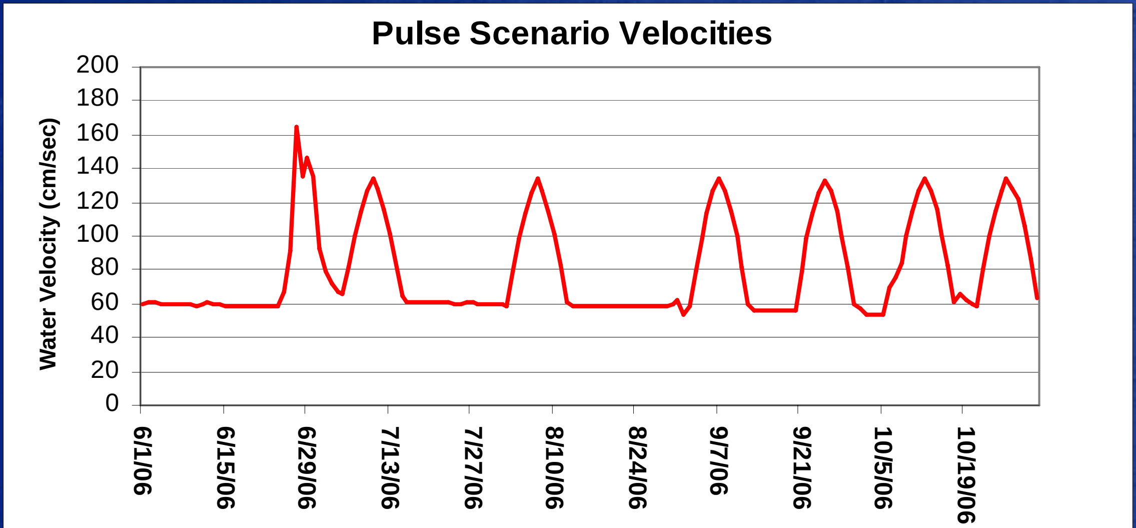


This dimensionless relationship is applied to the periphyton simulation in 2006 and illustrated using the City Park velocity and periphyton simulations

Flow Pulse Scenario – City Park Station



Day	Pulse Flow (cfs)
1	800
2	1400
3	2000
4	2600
5	3000
6	2600
7	2000
8	1400
9	800



One Natural Pulse at 3,480 cfs in June

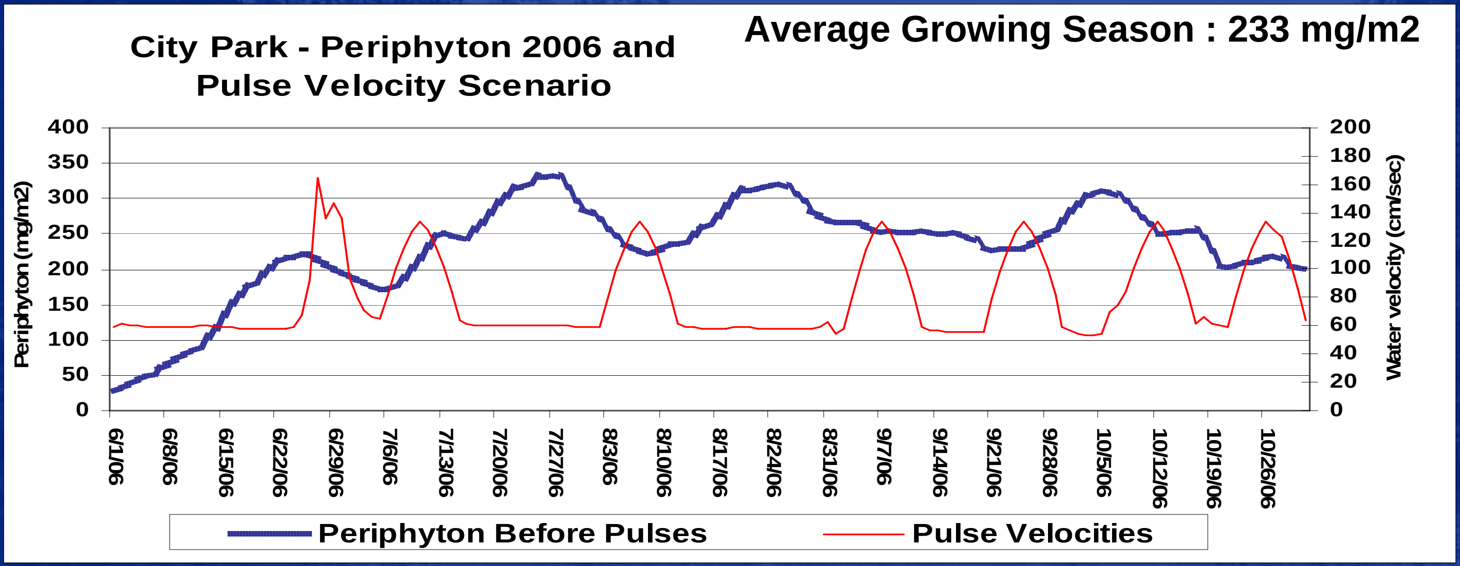
One 3000 cfs-Pulse in July

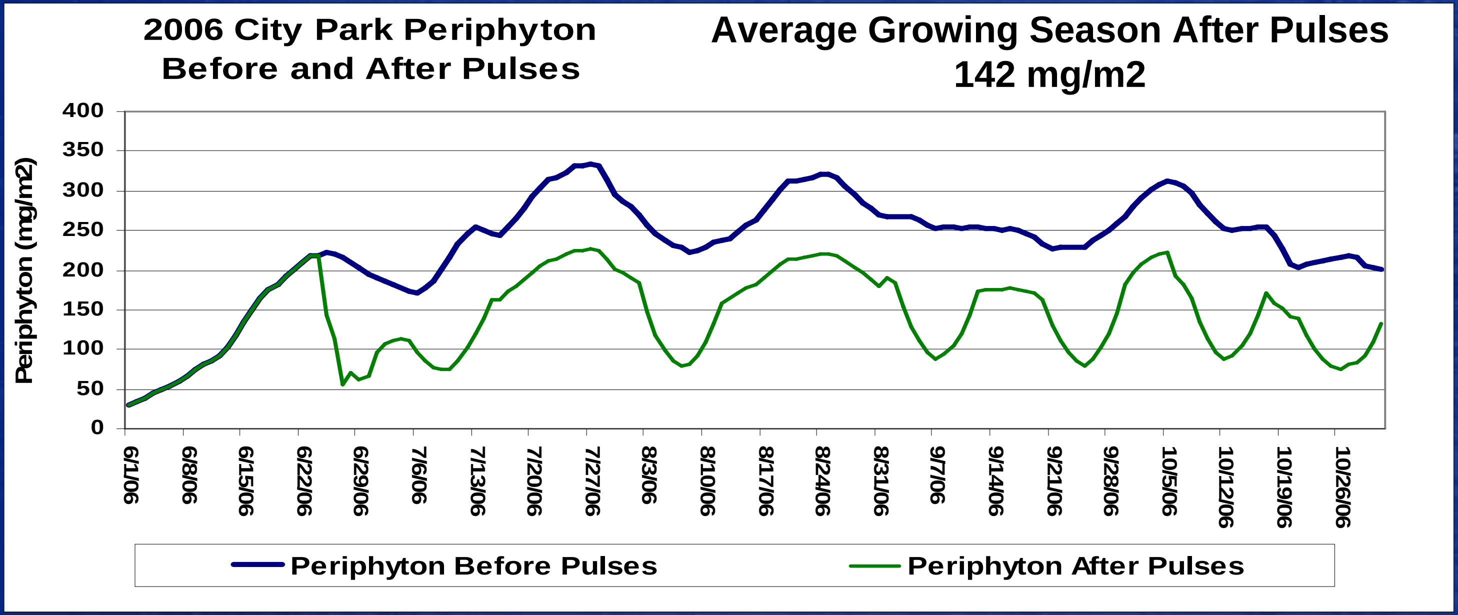
One 3000 cfs-Pulse in August

Two 3000-cfs-Pulses in September

Two 3000-cfs-Pulses in October

Flow Pulse Scenario





Flow Pulse Scenario

- Implemented using existing 2006 discharge conditions
- Reduced periphyton levels from 233 mg/m^2 to 142 mg/m^2 (39%)
- Indicates that with PO_4-P point sources reductions, a periphyton level of 100 mg/m^2 can be reached

Next Steps

- Develop allocation for point sources
- Finalize flow pulse scenarios
- Simulate periphyton and velocities after point sources reductions
- Apply pulse scenario
- Finalize allocations
- Finalize Draft TMDL report

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